INDUSTRIAL ECONOMY

AND

LABOR CONTROL

INDUSTRIAL ECONOMY and LABOR CONTROL

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To

GWEN AND LOLA

PREFACE

This book is chiefly concerned with the effective utilization of manpower and with the advantageous use of machinery, tools, equipment, materials, and floor space. It is broad, general, and elemental in scope, and it is designed for the use of (1) those who perform manual work, (2) supervisors and business managers who wish to teach their employees how to work more effectively, and (3) by those who wish to begin training themselves for professional time and motion study work.

The term "motion study," as used in this book, is applied to the study of all operations performed by workers with the purposes in view of eliminating as many unnecessary and useless motions and tasks as possible and of increasing the effectiveness of workers by improving: (1) work techniques, (2) the sequence of operations, (3) the handling and flow of materials, (4) the arrangement of workplaces, and (5) the environment of workers. In fact, all matters which affect manual operations in any way are considered to be within the purview of the motion-study analyst. The principles of the subject have been developed over a number of years from the observations and researches of a multitude of men and women. These principles are extremely useful as a means of stimulating thinking and developing originality in the solving of certain kinds of production problems. But in spite of the fact that the use of motion study has saved enormous amounts of time, effort, and money, its principles are, for various reasons, still widely ignored by industry. Although this book draws, to a limited extent, upon the author's ten years' experience in industry, it draws mainly from the work done by the many writers in the field, all of whom owe a debt of gratitude to the pioneers in time and motion study: Frederick W. Taylor and Lillian M. and Frank B. Gilbreth. Its form and content

have been shaped and tested during the past three years with the help of the author's students in the regular university classes, extension classes, and federal war training class at the University of California. It was written at a time when the need of war industries for more personnel, caused by abnormal growth, was greatly aggravated by the operation of the Selective Service System, which, early in 1943, was taking 12,000 men a day for the armed services. In the face of a steadily diminishing supply of available personnel it was apparent that if the flow of essential machines of war was to continue adequately to supply a constantly increasing fighting force, certain steps would have to be taken: (1) those who were not subject to call for military service would have to work more hours per week, (2) more women would have to be employed, and (3) operations and tasks would have to be planned so as to make use of available personnel in a more effective manner. The objectives of time and motion study are directed toward the last of these three steps. When properly applied, they get the most out of human energy by systematically discovering and eradicating wasted and unnecessary motions, not by speeding up the workers.

It is assumed that the reader will study this book with the expectation of putting the knowledge he acquires to immediate use in saving time, reducing fatigue, and increasing production. Consequently, questions are provided in order to give the student practice in applying the objectives and theory of time and motion study to practical situations. These questions should be useful in guiding class or group discussions. The student who is employed in a factory or an office will be in a position to apply his knowledge to concrete cases immediately. But others need not lack for sufficient practice, for many repetitive operations susceptible to improvement are performed on the farm or in the home.

It is a truism that the more one puts into a subject the more he gets out of it. This axiom seems to apply with peculiar force, however, to motion economy. If the objectives are not applied, they become almost meaningless—sometimes even ludicrous—to the reader. It is essential,

therefore, that this book be read actively—and if everyone who reads it is helped to increase his efficiency as a worker, even by a small amount, its writing will have been amply justified.

Acknowledgment is made of the courtesy of the following firms for permission to use pictures and examples illustrating particularly effective methods: Armour and Company, Chicago; Chicago Mail Order Company, Chicago; General Electric Company, Schenectady, New York; Norris Stamping and Manufacturing Company, Los Angeles; Pacific Division, Bendix Aviation Corporation, North Hollywood; and Produc-trol Los Angeles Company, Los Angeles.

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May, 1945

CONTENTS

PART I

APPROACH TO INDUSTRIAL ECONOMY AND LABOR CONTROL

PART II

THE PURPOSE OF THE OPERATION

PART V

TIME STUDY

PART VI

SECURING THE APPROVAL OF MANAGEMENT

PART I

APPROACH TO INDUSTRIAL ECONOMY AND LABOR CONTROL

Chapter 1

THE NEED FOR TIME AND MOTION STUDY

The general application of the principles of time and motion study results in lower costs, more goods, and higher levels of living. As the use of machinery lessens the amount of human labor required per unit of product, so does the use of time and motion study serve to reduce the amount of work required to attain a given result. Since the primary objective of time and motion study is to reduce labor, it, together with other devices for increasing efficiency, has been blamed for unemployment. The ill effects of unemployment, however, result from the unevenness with which changes in efficiency are effectuated, and from inequality in distribution of the savings which result from the use of more effective methods. The remedy lies not in the abolition of efficiency but in the temporary protection of those who otherwise would suffer from the changes which throw them out of employment. The benefits of better work methods can be seen readily from the following line of reasoning. Suppose everyone increased his own efficiency 100 per cent. All would work half as long and no one would suffer injustice, for all would be in the same relative position and, if leisure be considered an asset, society would benefit through being able to satisfy its wants for half the cost in labor. Human nature being what it is at the present time, we may assume that gradually the wants of society would increase until eventually everyone would be working as long and hard as before, and more goods and services would be produced. Thus, in the long run, an increase in efficiency in our economy results in a rise in levels and standards of living. More will be said in Chapter 2 concerning the benefits of increased efficiency from the standpoint of the worker.

TIME AND MOTION STUDY DEFINED.—Writers vary widely in their concepts of the subject matter which time and motion study should embrace. All agree, however, that time study, as developed by Frederick W. Taylor, and motion study as originated by Frank B. and Lillian M. Gilbreth, not only closely supplement one another but, as a matter of fact, overlap to a considerable degree. Their dependency upon one another, as well as their differences, will become apparent to the student as he progresses.

The field of motion study includes those activities which have as their purpose the discovery of better ways of performing manual work. The field of time study includes those activities which have as their purpose the determination of normal times required by normally skilled operators to perform given manual operations under standardized conditions.

In the past, both fields of activity were usually engaged in by the "time-study man." His orders were to time the essential operations in all jobs in a given department. As he observed the workers, certain improvements suggested themselves to him. Seeing no good reason why he should establish a time standard only to have the work to do all over again later, he attempted to put the improved method into effect before establishing the standard. Some writers have essayed to solve the riddle of whether the chicken or the egg came first by considering this example to be typical and theoretically correct. Actually it is of little importance whether motion study or time study should come first. Over a number of years many time studies and many motion studies may be made on each job. To say that "the one best way" should be found first and then, and not until then, it should be timed, is not true to reality. If time standards are needed for cost purposes, they are secured whether the motions have been studied or not. It is true, of course, that if the motion studies have produced an improved method the old time-standards no longer are applicable. It is not unusual, on the other hand, for time studies to be made on an operation before motion studies are undertaken in order to have a more accurate basis for figuring the savings resulting from the introduction of improved methods.

Whether the activities of time and motion study are grouped in one department or not, it is becoming increasingly evident that the individuals doing this work should specialize in one field or the other. Motion-study analysts, as distinct from time-study men, are included by many of the larger plants in their organization charts. In these concerns the time-study men make suggestions for improving operations, if any occur to them while they are timing the job, but their primary purpose is to establish time standards. The work of searching for improved methods is done by motion-study analysts. So, while time study and motion study supplement each other closely they may be separated, and often are, in actual practice.

A TOOL OF MANAGEMENT.—Time and motion study, as a combined field, is a tool of management, but whether it properly belongs in the field of "management" or of "engineering" depends upon the scope of activities which it embraces as well as upon one's definition of the terms "management" and "engineering." Some feel that it should be confined to the study of times and motions, and that such matters as plant layout, material handling, working conditions, etc., should be left to the industrial engineers. Since under these conditions there is little left of an engineering nature, the subject matter would be considered as being a part of the larger field of management. But, inasmuch as plant layout, material handling, working conditions, and other so-called engineering activities are so closely allied with motion study, it is not unusual for such activities to be included within the realm of time and motion study, the whole being considered as a branch of industrial engineering. When this viewpoint is adopted it is necessary to distinguish between motion study as applied to the individual, and motion study as applied to the department or the plant. The latter is often denominated "over-all" motion study.

THE PLACE OF THE ANALYST IN THE BUSINESS ENTERPRISE.—The time- and motion-study analyst occupies a peculiar position in industry. His primary purpose is to increase the effectiveness of labor and to crystallize methods in the form of time standards. But as he observes workmen and their methods he also may observe (1) that poor il-

lumination is decreasing the effectiveness of the operator, (2) that machine controls are badly located, (3) that certain machines could be arranged differently to good advantage, (4) that a different material would make the processing easier, (5) that a slight change in design of the product would reduce labor costs materially, or (6) that working conditions are bad. These all are factors bearing upon his work. Frequently, too, the workman may call the analyst's attention to changes that should be made: the bench is too high or too low, the chair is uncomfortable, a light glares in his eyes, he has to bend over unnecessarily, etc. So the question of the field of the time- and motion-study analyst resolves itself into this: primarily, it is the study of the motions of individuals performing manual labor, and the improvement, description, and timing of those motions; but it includes, secondarily, attempts to remove, add, or otherwise change any condition if it may reasonably appear that such change may result in increased labor effectiveness. The analyst does not design and construct the building or lay out the machinery or equipment, but where it appears that some feature of construction or layout, if altered, would result in a net gain to the company, the analyst attempts to put the change into effect. If a slot, instead of a hole, would solve an awkward assembly problem the analyst calls the matter to the attention of the designer. The analyst does not lay out the plant—he suggests improvements. The analyst does not design the product or specify the materials —he suggests refinements or substitutions. The analyst does not design or specify the machinery—he designs gadgets (simple jigs, fixtures, tools, and other mechanical aids) and he makes suggestions concerning improvements in the locations of controls, the use of material-feeding devices, methods of disposing of the finished part, etc. He is interested in all of these matters only insofar as they affect labor.

It might seem that if the designer, the industrial engineer, and the production engineer did not make mistakes there would be no need for motion study. This is partly true. These people may have a viewpoint that is organization-wide in scope; or they may see the problems of pro-

duction from the standpoint of the customer, the product itself, or the materials used. Unless they have been trained in motion study they do not think in terms of the motions used by the man or woman who carries out their plans. The designer may turn out a beautiful piece of work from the standpoint of the sales force and correctly done with respect to the materials to be used and the mechanical processes to be performed upon it—but if the detailed motions needed to process and assemble the article are not visualized, the labor cost and the time in process may be unnecessarily high. But the designer, highly specialized in his work, may say that he cannot anticipate everything when he designs a product or a part. Just as he submits his sketches to the sales manager and the production manager for their comments, suggestions, and approval he should seek suggestions from the motion-study analyst. The best designer is not necessarily the most original and it is not a sign of incapacity to solicit suggestions and comments. Likewise, the engineer who lays out a plant, if he is not versed in motion-study principles, could do a far better job from the standpoint of labor economy if he asked for the help of the motion-study analyst.

Often it is impossible to appraise correctly in advance such things as the effect a given design will have on sales, the suitability of a given material, or the adequacy of a proposed layout. Those responsible for making a change do the best they can, then wait for trouble to appear. It is the peculiar province of time and motion study, because of its proximity to the worker, to detect and help iron out the "bugs" which are almost certain to develop whenever changes in industry occur. As for the changes themselves —there is one thing we can be certain about in industry: that it will change as time goes by. It is the job of both the analyst and the observer to keep these changes as uniform as possible. A small change in the number of units processed in a given time often has a profound effect upon a plant. Such changes occur in response to the changing desires of the public. A novel feature of an existing product, when introduced to the market, may enable salesmen to exploit the product with such ease as to place unprecedented

demands upon production facilities of one plant, while the facilities of competitors may be used only to a fraction of their capacities. New materials may be developed or the prices of existing materials may change, thus forcing substitutions. The labor supply may change, new processes may be discovered, new machines may be invented—all of which introduce factors which force certain modifications in procedure. It is often true, however, that within a plant there is resistance to the series of changes which should follow these modifications. It is said that whipstocks were installed on the dashboards of the first automobiles. Of necessity, when motors were installed in buggies, shafts were discarded, but the other adjuncts of a horse-drawn vehicle were retained through inertia or even active opposition to change, and were discarded very gradually. One of the aims of time and motion study is to prevent the wasted human effort which results when lack of coordination prevents the adjustments which should follow every important initial alteration in industry. Assuming that a perfect job is done designing a product, specifying materials, and building and laying out a plant, there still is need for the work of the motion-study analyst and the critical questions of the time-study observer, for no sooner is a new product put into production than external conditions begin forcing changes.

The analyst uses techniques that are designed to stimulate original thinking. The things he suggests often seem to the supervisor, the worker, and the engineer to be highly unorthodox. He tactfully persists until the new method is given a trial or at least until it is proven impractical. The analyst is an idea broker. He is a clearinghouse for ideas that might result in decreased labor costs. He is the catalyst that brings together those who have ideas and those who have it in their power to put the ideas into effect. While incapable, as a rule, of doing the work of the engineers, designers, workmen, etc., the analyst, nevertheless, is in the unenviable position of one who must correct occasional errors and help improve the work of others. Like the motion-picture director who coordinates the efforts of many (though he may not be able to design and construct a set,

operate a camera, or even act), the analyst knows a good performance when he sees one and he knows how to go about improving a poor one.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. If you were among a group of five, shipwrecked on an uninhabited island, you would, naturally, welcome the salvage of small tools and such machines as would lighten the burden of feeding, clothing, and sheltering the group. Why, then, under conditions of civilization, should a worker ever resist the introduction of more efficient machinery? In what ways could the worker's objections be overcome?

2. In what ways does the introduction of time and motion study resemble the introduction of a new machine?

3. It has been said that time and motion study is just another way of speeding up workers. What do you think?

4. Distinguish between time study and motion study. Why are they often considered as covering more or less the same subject matter?

5. What activities are included in the term "over-all" motion study? What connection is there between such activities and those engaged in by industrial engineers?

6. The time- and motion-study analyst makes suggestions for changes that will enable labor to be used more effectively. He must, therefore, be prepared to have many of these suggestions rejected. Why might the following suggestions be rejected?

a) Brass should be used instead of steel—it can be machined and finished more easily and cheaply.

b) Pork trimmers in a meat-packing plant could work more effectively in warmer temperatures than those now maintained (approximately 35 degrees F.).

c) A design change to permit the use of bolts and nuts would require less labor than the present design which calls for welding.

d) By rearranging the ten machines in Department X, labor costs could be reduced ¼ of a cent per unit of production.

7. The motion-study analyst eliminates useless motions and works out shorter and easier methods of doing work. Why can not the worker or the foreman be intrusted with this function?

8. Time- and motion-study departments have primary and secondary interests. Name as many as you can of each.

Chapter 2

LIMITATIONS OF TIME AND MOTION STUDY

The techniques of time and motion study are used for the purpose of attaining one or more specific objectives. The ultimate purpose of attaining these objectives is that of making manual operations more effective in accomplishing tasks. Students of time and motion study very frequently become unnecessarily discouraged and disillusioned because they do not have a clear idea of its limitations. They learn its techniques and objectives and, quite naturally, they seek to apply them to concrete situations. What they often do not realize is that all of the techniques cannot be used and all of the objectives cannot be realized on every task that might attract the attention of the would-be analyst. There are physical, economic, and mental limitations to the use of time and motion study, and the chances are that the beginner will run into situations where his particular concept of time and motion study will be out of line with reality. This situation often is incongruous or extremely ludicrous and the beginner tends to jump to the conclusion that time and motion study may have worked elsewhere but "it cannot work here." So before considering the subject matter of time and motion study it is important to know something of its nature and something concerning the difficulties in the way of using it.

VARIABLE NATURE OF MOTION STUDY.—No two time or motion studies are of exactly the same degree of difficulty or intensity. Motion studies also vary with respect to the objectives they seek to attain. (The objectives of motion economy are considered in Chapter 12.) The two-way variability of motion study is illustrated in Figure 1. This chart is a device for aiding the thinking of the student. The figures are the crudest sort of approximations—they have

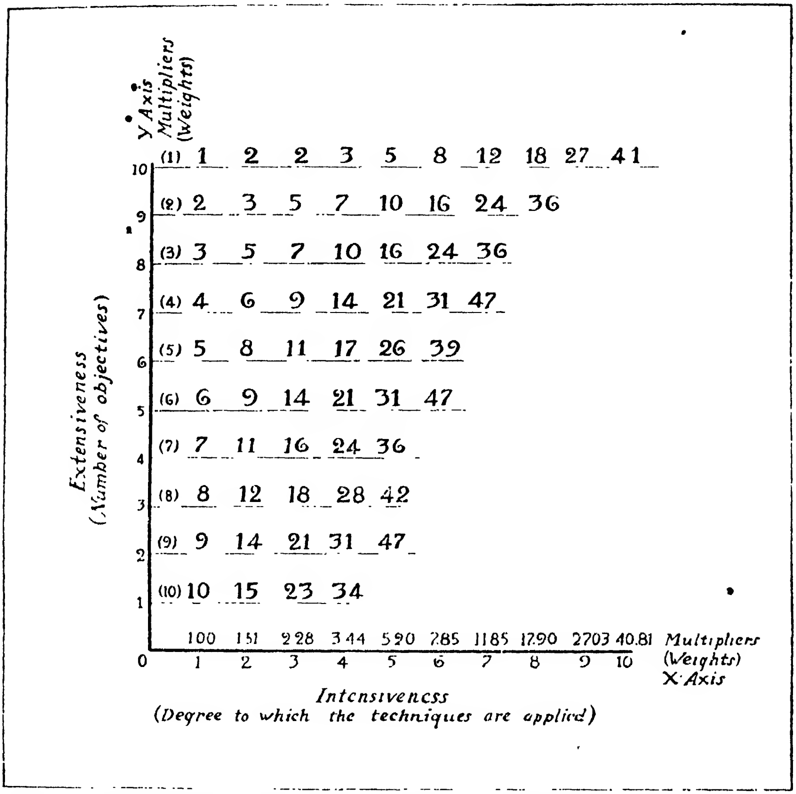

FIG. 1.—*Chart illustrating the two-way variability of motion studies.*

no significance other than to indicate relative values. In interpreting them the reader should guard against a tendency to impute to them the exactness they seem to imply. The x-axis, labeled "intensiveness," represents the care, time, expense, and techniques used in making a given study. The y-axis, labeled "extensiveness," represents the results accomplished by the study. Distance on the y-axis indicates the number of objectives accomplished multiplied by the number of operators affected. By using ten steps it is not intended to imply that there are only ten possible objectives—the diagram may be expanded up and to the right an indeterminate distance. While the (light) figures along the

y-axis must of necessity represent steps or jumps of appreciable magnitude those along the x-axis are arbitrary divisions of what represents a continuously increasing amount of time and effort expended by the analyst in attaining a given number of objectives. The horizontal lines indicate the continuous nature of "intensiveness" and the absence of vertical lines indicates the discontinuous nature of "extensiveness."

The heavy figures indicate approximately the relative desirability of attaining the number of objectives indicated (on the y-axis) by the expenditure of the relative amount of time, money, and effort indicated (on the x-axis). The application of an amount of intensiveness represented by the numeral one (which represents a very cursory analysis) might, in a given case, result in the attainment of any one or more of a number of motion-study objectives. It is impossible to say, in general, that the attainment of two objectives is twice as desirable as the attainment of one, and that the attainment of three objectives is three times as desirable, etc. But in this chart it is assumed that the desirability of attaining the objectives varies in direct proportion with the number of objectives attained. The relationship is indicated by the multipliers in parentheses along the y-axis. The multipliers in parentheses along the x-axis form a geometrical progression and are intended to represent the tendency that equal increments of effort added to the solution of a motion-study problem yield less than proportionate results. Each heavy figure, then, represents its y-axis multiplier times its x-axis multiplier.

Referring to Figure 1, it is readily seen that the most desirable motion study is one which yields a maximum of results with a minimum of effort. Heavy numeral one indicates the type of situation in a given plant or department that should be standardized first. Should the analyst then proceed to employ cursory analysis in the improvement of jobs less capable of improvement, or should he employ more techniques and give more time to the improvement of operations on which it is reasonably certain that results approximately equivalent to those previously attained would result? According to the chart it makes little difference

whether the analyst makes a study of second or third degree intensiveness, with ten objectives attained, or a first degree study with the attainment of nine objectives. Likewise, a fourth degree study accomplishing ten, a second degree study accomplishing nine, and a first degree study accomplishing eight objectives all are approximately of equal desirability. But from this point on, the desirability of applying more intensity rapidly diminishes, as the heavy numerals **5**, **8**, **12**, etc., indicate. The analyst who follows the order of magnitude of the heavy figures would make cursory studies throughout his entire jurisdiction, even though such studies yielded as little as one objective, before he would make a seventh degree study which would be sure to attain ten objectives. And he would make the most intensive (ninth and tenth degree) studies only where he was sure to attain ten objectives. Attaining fewer objectives probably would be economically unsound. And where he was certain that only one objective could be attained it very likely would not pay to make a study of more intensiveness than the fourth degree. Under such circumstances the number of cases would be limited (1) because of the obvious impossibility of attaining more than one objective due to physical conditions, (2) because the expected savings resulting from the improvement would not pay for the expense involved, or (3) because of a combination of these two factors. Such highly refined motion studies should not be undertaken, even though physically feasible and economically justifiable, until other more desirable operations have been studied and improved. There is no doubt that the operation could be improved—*every* operation can be improved—but the important thing to remember is that the analyst not only should know how to make time and motion studies, he should be a good diagnostician, as well. He should not prescribe a five-hundred-dollar operation and a trip to a rest home as a cure for green-apple cramps.

Whether one first undertakes to accomplish ten objectives on the eighth degree level of intensity (heavy numeral **18**) or to accomplish three objectives on the third degree level of intensity (also, heavy numeral **18**, denoting equal desirability) would depend upon the amount of equipment at the

disposal of the analyst.[1] Those concerns whose products represent a small proportion of labor cost generally do not engage in time and motion study on the more intensive levels. It pays such concerns to concentrate most of their attention on other factors such as overhead or materials, whichever accounts for most of the cost.

Figure 1 does not apply to time study. Although there are various techniques requiring greater or less degrees of intensiveness, there is only one objective involved—that of getting a time standard. And while it is true that it would not pay in most cases to employ refined techniques, great accuracy, and considerable time to obtain time standards, it is also true that not as much attention is paid by the businessman to the economic status of individual time studies as to that of individual motion studies. Time study furnishes information which is considered essential by modern management, and executives generally do not question the cost of individual studies. On the other hand, each motion study must justify itself economically. No study should be made that will not result in more than sufficient savings to pay its way.

PHYSICAL LIMITATIONS.—The common sense of the analyst should tell him when it is impracticable to make time and motion studies. Situations which require considerable planning cannot easily be standardized. The work of the executive, supervisor, tool maker, and research chemist are cases in point. But even these jobs have elements which can be studied with profit. If, for instance, successive jobs performed by such individuals have any elements in common, these elements can be standardized. It is impracticable to make time studies for cost or control purposes unless the daily performance of the operator can be checked easily. In a soap factory, for instance, the production of the packers can easily be checked. Washing or repairing soap racks, scrubbing floors, and maintaining equipment are, on the other hand, jobs which are independent of the production line. Such jobs require a special check which often is very difficult or even impossible to get satisfactorily. This ques-

[1]This book is written for those who probably will not exceed a degree of intensiveness of five.

tion of checking production is one which often taxes the ingenuity of the time-study man.

ECONOMIC LIMITATIONS.—As was previously mentioned, motion study is more rigidly controlled by economic limitations than is time study. Presumably, however, the time-study man uses common sense in striking a balance between the importance of a study and the time he spends on it. Usually the more important elements of a time study occur with more frequency and regularity than the less important elements, and hence are more easily studied. Time-study men, especially scientific-minded individuals, often get tangled up in such problems as the determination of the time that should be allowed per box for the element "wait for elevator" in a standard for hand trucking, when this element involves a very small proportion of the whole time. As unsatisfactory as this element is it usually must be included in the time allowed for the job. On the other hand, an unsatisfactory element of a motion study can be ignored without affecting the remainder of the study. For example, all of the objectives may be accomplished on a given job except that of "drop delivery"[2] of the finished product. It may be that the nature of the product is such that drop delivery is not feasible, except by the use of a complex and expensive mechanical device. By ignoring drop delivery, the analyst would not jeopardize the savings which might result from putting other objectives into effect. As a matter of fact such savings might be wiped out if he insisted upon spending the time, effort, and money necessary to develop a workable drop-delivery system.

There are several typical situations in which a motion study may be economically inadvisable:

1. *After a previously made motion study which resulted in the accomplishment of a substantial number of objectives.* Although a given objective has once been attained there is no reason why the same objective cannot be realized again, in a subsequent study, in a more refined and successful form. It may be that as a result of a first degree analysis the sequence of operations is changed, with the

[2]A term which is applied to the moving of materials by gravity. See Chapter 13.

result that a saving in time is accomplished. Subsequently a fifth degree study can, very possibly, result in further improvements in the sequence of operations which, if put into effect, would result in another saving. But, as was explained in connection with the discussion of Figure 1, the expense of the second study might well exceed the additional saving which could be realized.

2. *A highly mechanized operation in which the ratio of labor cost is small as compared with the total cost of producing the article.* This situation is similar to that just discussed.

3. *When temporary conditions exist.* Often a motion-study analyst sees a bad situation which he does nothing about, for by the time he could make a study and put the improved method into effect the order would be filled and his time would have been wasted. The time-study man, likewise, can waste his time under similar circumstances. Noticing a new product being fabricated in the plant he can spend a day working up standards to be used for labor control purposes, only to discover the following day that the order has been completed. Of course, if the standards were for cost or estimating purposes the time spent would not have been wasted.

4. *When the extent of repetition is not great.* Development jobs or situations in which there are no well-defined elements, even though they may last for a long period of time, are impractical from an economic standpoint to standardize.[3]

MENTAL LIMITATIONS.—Mental obstacles to the introduction of time and motion study may be a result of the prejudices, inhibitions, and habits of (1) the person who is making the study, (2) the operator, (3) the foreman, or (4) anyone else who has any influence on the method of doing the piece of work being observed. Some of these obstacles are considered briefly in the remainder of this chap-

[3]For excellent discussions of the question of time and motion study economy under varying conditions see Barnes, *Motion and Time Study*, John Wiley & Sons, Inc., New York, 1940, pp. 17-21, and Maynard, Harold B. and G. J. Stegemerten, *Operation Analysis*, McGraw-Hill Book Company, Inc., New York, 1939, pp. 27-70.

ter. The reader will recognize most of them and undoubtedly will be able to add more to the list. It is important to realize why improved methods, often worked out with the expenditure of considerable mental effort, physical labor, and money, are not put into effect, for if the reasons they are ignored or rejected are not comprehended, the analyst is apt to react in a way that causes unnecessary friction with his employer.

One of the greatest obstacles to the introduction of improved methods results from belief in the "mouse-trap" philosophy. However true it is that the world beats a path to the door of the inventor of a better mouse trap it definitely is not true that in all cases ideas for improved methods will be snapped up by management and put into effect. In most cases even the best ideas must be put in clear understandable form and then "sold" to the boss. Human beings do not accept new ideas very readily. It is even advisable for the employer to "sell" his idea to the workmen. The employer may be within his rights when he orders his employees to do this or that, but just because a motorist has the right of way does not mean that he has immunity from a smashup. Not only must approval of one's ideas be secured but they must be followed up. Ideas cannot put themselves into effect, and inasmuch as the originator is the most interested it is he who must keep pushing until his idea is adopted or until it is proved to be impractical. Every time-study man who has had the confidence of the workers has had many of them tell him about their ideas for making improvements in their jobs. Some of these ideas were surprisingly good and when the workers were asked what they had done about them, the tenor of the replies was that they "had told the superintendent one day and he had said to take it up with the foreman, who had never done anything about it." A case in point involved the failure of a tool and die maker to follow up one of his creations. The analyst noticed that two operators were kept exceedingly busy feeding parts into a can-seaming machine. It was his thought that a magazine for each part should be constructed with a simple revolving device for peeling off one blank at a time and dropping

it into the chute leading to the machine. Upon broaching the subject to the tool and die maker, the analyst was informed that such a device had already been constructed, and the analyst was led to a dark corner in the die room where the gadget was removed from the top shelf and unwrapped. The inventor and constructor was very proud of the device and would have liked to see it in operation, but he took the attitude that his responsibility ceased when it was built and shown to his superior. He was rather bitter about the way it was received, for when he showed it to the superintendent a noncommittal comment was made and the superintendent walked away. So in a spirit of revenge and resentment the tool and die maker carefully wrapped it up and put it on the shelf where it lay for over a year, losing money for the company at an approximate rate of 75 cents an hour.

The workman, although he knows more about his own job than anyone else, often is less able to make improvements on it than is an outside analyst. The reason is not that the workman is less intelligent, nor that he is untrained or inexperienced in making improvements, but that he has become so used to the present method that he tends to identify long usage with perfection. The argument against a proposed change in method would run somewhat as follows: "Young man, I have worked here thirty years, and no young whippersnapper is going to come in here and tell *me* how to run *my* job!" Often the argument points out the alleged fact that the old method is "tried and true." Or maybe the old timer says: "I've been using this method for over ten years, now, and don't you think someone would have found it out long ago if this hadn't been the right way to do it?" The writer once told a factory superintendent that the methods being used in a certain department were antiquated. This statement drew a storm of protest. His reply was: "Our methods in that department are *not* antiquated because *that's the way we do it.* True, a slight improvement might be made here and there, but as a whole our methods *must* be the best because they are the methods we have always used."

A closely related obstacle is that arising from a conflict

of authority in the mind of the operator. The operator (occasionally it will be a supervisor) opposes at every turn suggestions for improvement, because when he was broken in he was told, perhaps by someone he respected very highly, to do the job in a certain manner and he has come to believe that no change could possibly be of any benefit. If he had been told when he was broken in that "thirty pieces per hour is about right" he may resist any effort to set a time standard that squeezes out the loafing time and provides for forty pieces per hour.

Another obstacle which is closely allied with the last two discussed has to do with one's resentment toward personal criticism. Although a person's long familiarity with a way of performing an operation might blind him to its faults, there is no logical reason why he should resent criticism of the method. Nevertheless, there seems to be a very close connection between the methods people use in doing work and their egos. Tell the average person that he could get better results if he used a lighter hammer, that it would be safer if he held his chisel differently, or that he should hold the tool against the grinder at a slightly different angle and he resents it as a personal insult. Suggest to anyone, as a matter of fact, that what he does should be done differently or that his method should be changed and, though he may not show it, he feels resentment. The superintendent who fought back when he was told that one of his departments used antiquated methods betrayed his feelings when he defended a system for which he was responsible. He knew the methods were outmoded for he had asked for a report, and subsequently he put all of the suggestions embodied in the report into force. Another example of this type of obstacle has to do with the head of a cost accounting department who had worked out a formula for determining joint costs. When put to the test under actual operating conditions, the formula broke down and proved to be incapable of performing satisfactorily. One of the cost clerks in a branch plant showed the results to a member of the industrial engineering department who became interested in the problem and subsequently devised a workable formula. Every cost man who saw the

new formula was enthusiastic about it but, in spite of strong "sales" pressure and careful explanations, the official could never be convinced that the method he had devised could be at fault. So in spite of its inaccurate results the company enforced the use of the old method.

The next one is mentioned at the risk, perhaps, of overlapping some of the obstacles already considered. It is best described by the phrase "it can't be done." Anyone who does not want a new method put into effect seems to have a good weapon in this phrase. Such individuals will not allow a trial and permit the matter to be decided fairly, but will scarcely wait until the explanation has started before saying: "It won't work." The person who desires to progress will find many closed minds in his path.

Another obstacle in the way of better methods involves the matter of getting proper credit for ideas. It is only natural that the person who makes suggestions for improvements in methods, processes, machines, etc., should wish to receive credit and recognition. It is hard to say which incentive is stronger, money or recognition. If the person who devised the improvement always got both there would be more thought given to work simplification in industry. It is unfortunate when it is necessary, as it often is, for a person to work under a supervisor who always opposes his subordinates' ideas and then later promulgates them as his own. Yet even this situation is not as bad as it might seem, for such a supervisor is afraid of his position and secretly values a worker who can keep him supplied with ideas. A colleague of the writer's formerly had to put his ideas over by using this phrase: "I understand that this is your idea, boss, and I think it is a darned good one . . ." and he would proceed to outline the idea. The employer always agreed! The point is—the employee who is too sensitive about having his ideas stolen will not have many. Conversely, the person who has the ideas usually does not particularly care about who gets credit for them and, as a rule, he eventually gets the recognition he deserves.

Occasionally the proposed change is not opposed in principle, but the suggestion is made: "Let's let well enough alone." It is always easier, of course, to do this than to

calculate the net benefits, write the whole thing up in the form of a report, and then fight it through. The idea may stir up controversies and if it is adopted it may cause a disruption to the old familiar routine, with considerable unpleasantness, until the period of adjustment is past.

When a person gets into a rut he constitutes a real obstacle to progress. Such an individual, if he is a chronic case, has lost hope, ambition, and possibly all desire for a better position. He probably is happy in his daily routine and he not only resists efforts to change it in any respect but he even may refuse a promotion because it means new responsibilities which he feels unable to face. As a person gets into a rut he seems to lose last his desire for variety, that is to say, he continues making resolutions but as time goes *by he finds his power to carry them out gradually diminishing. His job and surroundings may not be particularly* pleasant but there is no pain like the pain of changing long-existing habits, so he continues to cling to the old job and resists every suggestion that he should change any detail of it. Often such an individual is asked by the foreman to break in a new worker. Thus the inefficient methods are perpetuated. Bricklaying is one of the world's oldest crafts, yet Gilbreth found that most of the energy used in the method that had existed for a thousand years or so was wasted. He was able to reduce the number of motions used from the conventional eighteen to only four and one-half.[4] The person who is in a rut resents suggestions that he should change his work methods for the reason that the new ones, though more effective, are strange and unnatural to him, and he sees no object in going to the trouble of breaking old habits and acquiring new ones.

One of the strongest obstacles to time and motion study results from a fear of ridicule on the part of workmen. Most people dislike being conspicuous if being so brings derision. The least that can be said of the first man to carry an umbrella through the streets of London is that he certainly was no coward. The lathe hand dislikes intensely being singled out for observation by the time study man,

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[4]Gilbreth, Frank B., *Motion Study*, D. Van Nostrand Co., New York, 1911, pp. 13 and 88.

and often he would rather resign his job than perform an operation in a way that was not conventionalized by long shop usage. It is this, rather than laziness, that explains the violent objections to operating more than one machine at a time, objections which often are raised by those who spend the bulk of the working day leaning on something and watching the machine operate automatically. Let a typist tie an eraser to an elastic and hang it in the most convenient position for quick use, directly above the platen, and she will become the cynosure of all eyes and the subject of considerable mirth. If she has the courage to hold out, she becomes the butt of countless jokes. But it often happens that others adopt the innovation and gradually the pre-positioned eraser becomes standard practice.

It is a commonplace that hindsight is better than foresight. Occasionally a supervisor will not cooperate in putting good suggestions into effect, or he may even actively discourage them, because *his* superiors give the impression that the supervisor is not competent if he cannot think of these suggestions himself. This situation may lead to idea stealing, which has been previously considered. The writer knew a plant manager who often passed along to the head office good suggestions made by his subordinates. Invariably a reply would come back something like this: "The proposed method is very good and we hereby authorize the necessary expenditure for putting it into effect, but what we cannot understand is why *you* did not think of this long ago." A manager could not be blamed for not encouraging suggestions from his subordinates if every idea adopted meant a reprimand for the manager. A motion-study analyst working under such conditions might well be completely baffled in his efforts to learn why his proposed improvements were not adopted.

Workmen are no different from anyone else in looking for advantages to themselves when methods are changed. It requires considerable encouragement to persuade a workman to change almost life-long habits of work, but the employer who promptly rewards those who produce more effectively soon establishes a reputation for fair dealing which

tends to break down resistance to the adoption of better methods.

In normal times a worker seems to object to the use of more effective methods most frequently on the score that he may "work himself out of a job." Unfortunately there is a very real basis for this obstacle. Workers will not suggest improvements nor will they cooperate in working out shortcuts if the net effect results in such a reduction in demand for their services as to put one or more of their number out of a job. Actually there is a social gain when goods are produced at a lower cost and theoretically nobody should object to an improvement in work methods that results in increasing output, but individuals and certain groups do frequently raise such objections—the reason being illustrated in the following example. Suppose that 1,000 products a day are processed by five men in Department A, 15 men in Department B, and 30 men in Department C. Suppose, further, that new work methods introduced in Department C serve to reduce the number of men needed. Unless corresponding improvements are made in Departments A and B, the personnel in Department C will have to be reduced. Since these improvements cannot be introduced uniformly throughout the plant, but must be applied to one operation at a time, every time there is an improvement of any consequence one or more workers are laid off. The employer would have no incentive to put improved methods into effect unless he could reduce costs. The most obvious way to reduce costs is to reduce the payroll. Of course he does not discharge a valuable employee —but if the improvement renders that employee's services unnecessary and if nothing else can be found for him to do, the employer is forced to discharge him. Employees who have observed employers following this line of reasoning cannot be blamed for making their jobs more secure by resisting suggestions that might result in increased efficiency. There is, however, a bright side to this picture. In the long run everyone usually benefits from increases in productive efficiency. The most efficient plant is in a favorable competitive position. If the lower production cost is followed by a price reduction, an increased demand

for the product may result and that would, in turn, enable the employer to rehire those men who had been discharged. Whether demand increased or not the employer could afford to pay somewhat higher wages. If the firm retained all of the savings, its financial position would be enhanced and the security of the employees' jobs would, as a result, be greater. No matter how we look at it, increased efficiency *in the long run* results in more employment, more profits, higher wages, and higher standards and levels of living. In spite of the undoubted fact that in the past there have been instances of discriminatory treatment, it cannot be successfully denied that employers are attempting to encourage suggestions from their employees (1) by keeping them on the payroll during the period following the introduction of the suggestion, (2) by using suggestion-box systems and by paying for valuable ideas, and (3) by keeping a record of those who are interested enough in their company to work more effectively, and by promoting such individuals. As for the individual who makes the suggestions—he has little to fear even though the payroll must be reduced, for an employer is shortsighted, indeed, who fails to make every effort to keep the man or woman with ideas and the courage and determination to carry them out.

Here and there one runs into union rules which serve to restrict production and which force union members to resist improved methods. Fortunately, however, unions are coming to realize that the only justification for higher pay and better conditions is greater productivity. Unions which restrict output, then bargain, get far less than those which produce, and then bargain, for the former make it harder and the latter make it easier for the employer to grant their requests.

This list of obstacles is by no means exhaustive. To it could be added many other examples of mental impediments to the adoption of more efficient methods. The student of time and motion study may, at this point, be somewhat discouraged at the prospect of putting his ideas to use. He will find, however, that when he begins making improvements in conditions surrounding his work he will

not necessarily encounter serious opposition. If he does, he has been forewarned.

ATTITUDE OF THE ANALYST.—As for specific methods of dealing with these mental objections, it has been said that the time-study and motion-study analyst spends ninety per cent of his time using salesmanship and ten per cent making studies. Whether or not this is anywhere near the truth it seems evident that the analyst who spends all of his time in the shop on technical problems and none on human problems will not be very successful. Hints on how to meet these human problems are mentioned, along with descriptions of the techniques of making studies, at various points in succeeding chapters. Since human beings are exceedingly variable in their behavior it is virtually impossible to draw up a blueprint for the analyst, explaining how to act in all of the various situations that will confront him. He can, however, go a long way toward success if he will observe the following rules of conduct.

The analyst who keeps himself out of the picture as much as possible gets farther. It is fatal to take the attitude: "It is my idea that a change should be made in your methods. *I'd* like to have you do things *my* way." The analyst must learn to get his own way by giving credit to others or by letting others get credit for the improvements. At first this is galling to his vanity but after a short time a sense of satisfaction in noting substantial accomplishment in the plant will compensate him. When it is obvious that the analyst has furnished the idea and a worker has only complied with certain suggestions, a "we attitude" will do wonders in opening the way to future improvements. For instance, in explaining the new method to the foreman the analyst could say in the hearing of the worker: "Bill and I worked this out and we believe we can save the company something." If a workman with a good idea confides in the analyst, he trusts him, and that trust should not be betrayed by doing less than giving full credit to the worker. There will be plenty of crackpot suggestions. These should not be dismissed too abruptly, but sufficient interest and time should be taken to point out clearly the reasons they cannot be used.

In general, a spirit of frankness should prevail in the relations of workers, analyst, and management. The professional analyst cannot adopt an air of superiority in the shop. Any feeling of mystery surrounding his actions should be dispelled as soon as possible. Some concerns instruct their time-study observers to adopt and maintain an attitude of aloofness in the plant. Such an attitude serves only to infuriate some workers and frighten the wits out of the others, and the writer can see little excuse for it. The most asinine policy of all, followed more or less widely, is that of making surreptitious time and motion studies. A program based upon anything but a spirit of frankness and cooperation from the lowest placed employee to the chairman of the board is foredoomed to partial or total failure.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Motion studies vary in intensity as well as with respect to the objectives they seek to attain. Classify the following cases:

a. A door-bell push-button assembly job has not been standardized. The analyst has good reason to believe that if he designs an improved workplace, he can obtain the cooperation of the operator in putting a substantial number of motion-study objectives into effect.

(1) Intensity: low, medium, high?
(2) Objectives: few, medium, many?

b. The assembly of electric shavers has previously been standardized and a substantial number of objectives have been attained. An analyst believes, however, that if he could study a motion picture film of the operation, construct charts showing the sequence of operations performed by each hand, and obtain the cooperation of the operators in experimenting with alternative methods, a better sequence of operations could be worked out. At the present time the operator lifts the assembled shavers from the bench and places them in a tote box. The analyst is especially desirous of working out an automatic drop-delivery system as a result of his study.

(1) Intensity: low, medium, high?
(2) Objectives: few, medium, many?

2. Should a high or low degree of intensity be employed when making time and motion studies in an industry which is evolving rapidly from a job-order, handicraft basis to a straight-line, mass-production basis?

3. Name the factors you would consider in deciding the degree of intensity which should be employed in making:
    a. Motion studies
    b. Time studies
4. "It is impracticable to make time studies for cost or control purposes unless the daily performance of the operator can be checked easily." Explain.
5. Give an example from your own experience of resistance to an improved method of doing work. Can you explain it?
6. If you were an employer, how would you combat the feeling workmen have that by slowing down they can make the work last longer?
7. If a workman offered an unworkable suggestion, what, in your opinion would be the most tactful way of rejecting it?

Chapter 3

INTRODUCING A TIME- AND MOTION-STUDY PROGRAM

Much of the value of a time- and motion-study program is lost because its introduction into an organization is bungled. It is the purpose of this chapter to present the steps which, if taken prior to the actual making of time and motion studies, will considerably smooth the way of the analyst.

MANAGEMENT CONFERENCES.—Before a successful time- and motion-study program can be inaugurated it is necessary to have a clear understanding with management as to what is involved. One method of introducing such a program is to ask an outside consultant to prepare the framework, after which the firm takes it over. Another method is to hire a capable time-study man (unless one may be found already within the organization) for the purpose of developing a department. In order that the new department may not later find itself working at cross purposes with the rest of the organization it is essential that the policies of the concern with respect to the time- and motion-study program be thoroughly considered. The head of the new department should be given an opportunity to explain the principles of time and motion study to the major officials. If possible, examples of results obtained from the use of time and motion study in other concerns within the industry should be supplied. Motion pictures showing examples of motion-study principles and improved work methods are available and should be projected at one or more of these conferences. It is helpful, also, in explaining what motion study can accomplish, to use a few demonstrations of correct and incorrect work methods.

Management will want to know what the program will cost, as well as what it may be expected to accomplish. The new department head will have to draw up organization plans for his department, personnel specifications, salary proposals, office space requirements, and needs with respect to equipment and supplies.

It is difficult to see how the program could succeed without the wholehearted support of the workers. Detailed plans should be prepared and all of their implications should be thoroughly discussed (1) for obtaining suggestions from the employees, (2) for providing incentives to encourage workers to follow the improved methods at better than standard speeds of performance, (3) for providing incentives for indirect labor and supervisors, and (4) for handling questions and possible grievances of employees arising from the operation of the new standards.

If it appears that the management proposes to use time and motion study as a speeding-up device, as a whip over labor, it should be explained that the resulting frictions which are sure to develop from such misuse of the program will nullify any advantages that might accrue to the firm.

The average employer expects to play fair with all concerned when the time- and motion-study department is installed. Unfortunately, however, a few employers unwittingly (sometimes deliberately) engage in practices that serve to throw insuperable difficulties in the path of the department. A few of these practices should be mentioned.

1. Management may bring pressure to have the standards "tightened up," i.e., changed so as to require more effort from labor without a corresponding simplification of operations.

2. Management may give lip service to the program but contribute to its failure by not providing interested cooperation.

3. Management may promise rewards for meritorious suggestions from employees, then hamstring the whole suggestion system by temporizing when it comes to paying for them; or the rewards paid may be unreasonably scant; or inadequate explanations may be made for rejected ideas.

4. Business managers, controlling as they do the purse strings of their organizations, often feel that they should issue orders and employees should yield blind obedience. Any tendency their supervisors display toward treating the workers as people with feelings is looked upon as a weakness and such "coddling" of labor is condemned by them. Any system that is imposed upon workers without their consent is not as effective as it might be and the difficulties of installing and maintaining it are almost insuperable.

If these, or other, unhealthful conditions are present, those sponsoring the new program must take immediate steps to correct them. Thus, it not only is necessary for the success of a program of time and motion study that the man selected to install it should be technically proficient; he must be fully cognizant of the multitude of problems of a psychological nature which must be faced and correctly handled.

Independent Status of the Department.—Much has been said in management literature concerning the proper place of time and motion study within the organizational structure of the business concern. The knowledge analysts must have of design, materials, processes, machines, equipment, schedules, routes, etc., is given as a reason by some for placing time and motion study under the plant engineer. The fact, however, that practically everything done by each analyst affects labor in some manner leads others to advocate a close organizational tie-up with the personnel department. The time- and motion-study department works closely, also, with the sales and cost accounting departments in making estimates, with the accounting department in connection with the preparation of budgets, with the cost accounting department in figuring costs, with the planning department in furnishing time standards for working out production schedules, with the industrial engineering department concerning proposed changes in methods, with the designing department concerning proposed changes in materials and designs, with the safety engineer concerning dangerous conditions, with the timekeeping and payroll departments in connection with bonus payments—as a matter of fact, there are few major departments which cannot benefit from

the work of time- and motion-study analysts. Because of its broad nature, it would seem to be a mistake to place the work of time and motion study under the supervision of any of those departments named. It is true that the plant engineer would be perfectly capable of supervising its engineering aspects, that the personnel manager could well supervise its personnel aspects, etc., but it is not so clear that each could supervise all phases. The logical arrangement from every standpoint seems to be to place the man in charge of time and motion study under the supervision of the highest operating official and to place this work on an independent departmental basis.

THE DEPARTMENTAL ORGANIZATION.—Before the head of the time- and motion-study department can begin his work of economy he must organize and train his personnel. The size of the department will depend upon several factors: (1) the size of the plant, (2) how much of the plant is to be covered, (3) how quickly it is proposed to standardize the plant, (4) the degree of difficulty involved in standardizing the various operations, (5) the degree of intensiveness to which operations will be studied, which in turn is largely determined by the amount of labor cost in the finished product as compared with other costs, and (6) whether or not the department will be independent of the office as far as filing, typing, calculating, and stenographic services are concerned.

There are definite advantages in starting small and expanding gradually. An enormous amount of preliminary work is necessary before time and motion study begins to show results. A small department is not likely to have pressure brought to bear for quick results. A small department, too, if it is managed properly will not encounter the difficulties which are sure to be met by a more ambitious program. It is essential that the workers be sold on time and motion study. There has been considerable misuse of time study in the past and the workers may be hostile. In addition, most people are suspicious of what they do not understand, especially if it affects their pay checks. If the program is started in a small way, it will be relatively easy to explain away the fears of small groups of

workers, who, as they begin to reap the benefits of the work of the department, become enthusiastic supporters of the program, thus making its extension vastly easier.

A possible disadvantage in starting with a small department is that the management may become so accustomed to it as to oppose later attempts to enlarge it. Perhaps a wise plan would be to outline at the beginning the requirements for a complete department, then, if objections are subsequently raised, the department head can point to the unfinished plan as his authority for expanding. Not much objection should be encountered, however, if the program is getting results.

One of the first matters to be decided is the name of the department and the title of its head. The alternate titles listed for this profession in the *Dictionary of Occupational Titles*[1] are: time-study engineer, efficiency engineer, efficiency expert, production manager, production engineer, production expert, time-study man, and waste-elimination man. The term "time study" includes in practice both time study and motion study and it is generally understood that an essential part of the work of the time-study department is the simplification of methods. Where the head of the department derives his title from the name of the department he could be called "head," "supervisor," or "chief" of the ——— department. Frequently the members of the department are known as time-study men and the head of the department is known as the time-study engineer. As for the name of the department, regardless of what it officially is, the workers probably will refer to it as the "efficiency department." A few names in common use are: "Time-Study Department," "Time Standards Department," "Methods Department," and "Industrial Survey Department," as well as various combinations of these names. To avoid confusion the following terms will be used throughout the remainder of this book:

The well-balanced *standards department* consists of three divisions: (1) *motion study*, (2) *time study*, and (3)

[1]"Part I, Definitions of Titles," p. 943, United States Government Printing Office, Washington, D. C., 1939.

clerical. The activities of the department are directed by the *head of the standards department.*

The *motion-study division*, composed of *analysts* whose job it is to find better ways of doing work, is headed by the *chief analyst.*

The *time-study division*, composed of *observers* who time operations and calculate standards, is headed by the *chief observer.*

The *clerical division*, headed by the *chief clerk*, performs a variety of duties. *Checkers* are stationed throughout the plant for the purpose of recording the hours worked and the amount produced by each employee on each different job. If the job is an unstandardized, or "day work," job, the amount of time is recorded but the amount of work produced is ignored. This information is furnished daily together with the standards applicable to each standardized job, and the "hours produced" and efficiencies of the workers are figured by the *calculators*. Periodic reports are assembled for the operating officials of the plant by the *clerical division*. If a wage incentive system is in operation, this division calculates the bonus payroll. As a rule it does not calculate standards. Best results seem to obtain when the *observers* figure their own time studies. Various other members of this division perform such duties as: typing standards, letters, and reports; filing standards, correspondence, and reports; and such special assignments as filling out questionnaires for governmental agencies.

QUALIFICATIONS OF PERSONNEL.—The qualifications of members of the clerical division are no different than those required for similar work in any other department, with the possible exception of the checkers. There are at least three avenues of promotion open to the checkers: (1) further advancement within the department through the time-study division to the motion-study division, (2) advancement in the operating department as an operating man or supervisor of production, and (3) advancement up through various positions in the concern's office organization. Individuals who seem to constitute likely material for time-study work often are assigned temporarily to positions as checkers until they are needed for the more difficult work.

A somewhat different type of individual is needed for time- and motion-study work than for supervisory positions. The supervisor has less need than the analyst or observer for powers of persuasion, for he occupies a line position, whereas the analyst and the observer occupy staff positions. The supervisor possesses certain powers of discipline over the workmen—he is the boss and represents the company. The analyst and observer are "outsiders" both to the foreman and his subordinates. These outsiders as a rule are not given any powers to tell a workman what to do and how to do it. Even their presence in the department often is at the sufferance of the foreman. While the foreman can direct his workers as a result of powers vested in him by his superiors, an analyst or an observer has the power to direct workers only by appealing to his superior (the chief of his division), who appeals to his superior (the head of standards), who appeals to his superior (the general manager), who may direct the superintendent to direct the foreman to tell his men to do what the "outsider" wanted done. And if the foreman had previously refused to cooperate with the analyst or observer, the atmosphere will by this time be well charged with electricity. Since it is obviously impracticable to follow such a procedure every time a time study or motion study is made, it becomes necessary to hire men and women to make such studies who can, by the power of their personalities, by their persuasiveness, by their good sense and good conduct, by their reasonableness, and by the respect which they command, get what is necessary from workers and supervisors in the way of information and performance, without resort to force from line authority. The requirements for success in this work are not any more stringent than are those for success as a salesman, as an executive, as a department head, or for any one of many other positions found in industry today. The fact that people in this work must obtain the cooperation of individuals in a wide variety of endeavor within the organization often leads to the mistaken belief that they must possess all of the characteristics of successful individuals in this wide variety of endeavor. After a lecture by the writer on this subject, one of his students

made this observation: "It seems to me that one has to be a genius to be successful in this kind of work." To name only one essential characteristic of an observer—ability to get along with both management and labor and ability to maintain a strictly impartial attitude when establishing time standards—it would require a genius to succeed in some organizations. But if management is fair, labor is not suspicious, and if other conditions in the plant are favorable, there is no reason why a person with normal intelligence, average attainments, and the usual personal qualities found among industrial employees cannot succeed in this line of work. The trouble with listing these personal qualities in a book is that essential qualifications merge imperceptibly into desirable qualifications, one trait of character suggests another, and one line of training suggests still another. Often people who lack certain equipment make up for the lack in other ways and thus succeed in spite of their shortcomings. A good head of standards should, nevertheless, try to choose individuals for his department who possess the basic personal qualifications of honesty, health, willingness to learn, good personality, the right amount of initiative, conscientiousness, a sense of responsibility, good judgment, self-control, correct conduct, tact, etc. Often a department head has the experience of hiring a likely-looking individual only to find later that he lacks reliability or initiative. Such an individual would fail in any position of responsibility. None of these personal characteristics are exclusive to standards department employees. It is desirable to emphasize, however, a few characteristics which are of considerable importance in time- and motion-study work. Analysts and observers must be (or they must soon learn to be) reliable, tactful, persistent, patient, accurate, intellectually honest, fair-minded, alert, responsible, and sympathetic. They must have (or they must soon develop) a pleasing personality, the knack of persuasion, a liking for the people they work with, tolerance, a liking for the industry in which they work, an honest desire to be helpful, a liking for mechanical devices, orderliness, good judgment, considerable energy, analytical ability, teaching ability, self-confidence, and creative imagination. Although somewhat differing qualities

are required of analysts than of observers, these are generally considered to be the minimum requirements for either position. Analysts require considerably more persuasiveness, creative imagination, and tact than observers need. The analyst must use imagination in devising improved methods, in securing the cooperation of many individuals, in obtaining information from those who know more about materials, processes, speeds, etc., than he does. He must overcome the prejudices of workers and supervisors until the operation has been improved and he must keep in mind all the while that time cannot be wasted on ideas that will not pay in the long run. The analyst should be a higher type person—one with more experience and maturer judgment—than the observer.

As for educational requirements it seems to be agreed by most who have expressed themselves in the literature of management that a high school education is essential for both analysts and observers. Beyond that are only "desirables." A few highly desirable acquisitions are: a command of good English, the ability to sketch, a knowledge of salesmanship, and familiarity with the slide rule. Courses in engineering and business administration are useful. The shop courses, machine drawing and design, and mathematics are among the most valuable contributions of engineering, while personnel administration and labor problems, statistics, economics, psychology, industrial management, and cost accounting constitute the most useful courses provided in business administration. A good course in time and motion study is, naturally, of considerable value. Such courses are offered both in schools of business administration and in schools of engineering. Surprisingly enough, a good working knowledge of grade school arithmetic is essential for both analysts and observers. Higher mathematics come in handy; algebra and geometry are used occasionally, descriptive geometry aids in visualization but is not used directly, analytics is useful, but calculus rarely is used. The processes followed in observing and calculating time standards are those of the statistician, and familiarity with statistics is of great value to the observer.

TRAINING STANDARDS DEPARTMENT PERSONNEL.—The

head of the standards department will give his subordinates every opportunity to progress. Checkers who wish to work into observers' positions and observers who wish to become analysts should be told how to fit themselves for added responsibilities. Often evening classes are conducted at the plant for those who wish to strengthen themselves in arithmetic and other subjects. Members of the department are encouraged to take correspondence courses or university extension courses in subjects which might be beneficial to them and to the organization. Analysts and observers are strongly conscious of the importance of their profession and many of them affiliate with the Society for the Advancement of Management, the American Management Association, the American Society of Mechanical Engineers, and other professional organizations.

A good plan, which is followed by many standards departments, is that of meeting periodically to listen to talks on a variety of subjects prepared and delivered by members of the department. Usually these talks are followed by questions and general discussion. Where such meetings are held they may, also, provide opportunities, if such are needed, for training the personnel of the department in certain desirable personal traits. Usually it is not necessary to tell analysts and observers how to dress. A new member of the department will take his cue from those he sees working around him, and they in turn look to the head of the department not only in matters of dress but of conduct and attitude toward others, as well. It may, however, be necessary to call attention to some dereliction, or to the necessity for developing some desirable trait; perhaps the best way is to speak briefly, but to the point, at a departmental meeting.

Conduct in the Plant.—In many plants time-study observers are most heartily despised. Such observers attribute this dislike to the nature of their work, and do nothing to overcome or prevent it. A young lady in one of the time-study classes on the Los Angeles campus of the University of California informed a friend of her interest in the subject. He said with considerable heat: "Oh! How I hate those time-study men!" Quite naturally she was desirous

of learning why, and, in answer to her question, he gave as his reason: "All they do is come out to the department and watch us. They never say anything—just stand and look at us all day." Outside the plant such conduct would be considered to be rude. The correct procedure for most plants should involve an introduction by the foreman to the worker (at least the first few times the observer or analyst appears in the department). One of the most effective methods of introducing an observer to a gang would be for the foreman to call its members together and say: "This is Mr. Jones, who is out here to get the time required to wrap and pack these number 825's so they can figure up in the office what the costs are. Now, do whatever Mr. Jones asks you. Don't work fast and don't slow down—just work as you always do. I'll be in my office, Mr. Jones, and if I can help you in any way, let me know." With such a send-off more than half the battle is won. Studies made under such conditions are certain to be much more satisfactory than those made while the observer (1) stands behind a post, (2) looks at one operator and times another, (3) gets the time with the stop watch hidden in a pocket—a few methods that actually are used. If the foreman will not cooperate, probably something is wrong higher up. The program has not been properly introduced to the supervisors. They have never been given the impression that the management is solidly behind it.

Even if management has bungled. it is not by any means impossible for a tactful stranger to become acquainted and liked in a department. Once this has been accomplished it should not be difficult to secure the cooperation of the desired operator. If the worker asks for information concerning the study, it should be supplied in non-technical language. Workers usually are curious about the stop watch, and if the observer satisfied their natural desire to know what he is doing, much of the nervousness, fear, or suspicion they may have felt should disappear. One of the devices used by market research people for getting cooperation in filling out questionnaires is to offer to send the results of the survey to those who help in furnishing the requested information. When a choice is offered as to whether or not the results should be furnished, almost invariably the reply

is in the affirmative. Workmen who are being timed are no different. They are curious to know the results of the study, and if they ask for the standard, there is little to justify evading the request or refusing to supply the information. Time standards frequently are used in the form of decimal hours per hundred units, but for the convenience of those who wish to know how many units must be produced in a given time in order to meet the new standards it is customary to express them in terms of units per hour, as well.

The successful analyst or observer is not too much of a "good fellow," either in the plant or toward his superiors. He meets everyone naturally. He is in the difficult position of drawing his pay from management and at the same time trying to be impartial between management and employees. This difficulty is more apparent than real, however, for every staff employee in the organization is hired for his professional knowledge and all are the more respected if they fight for what they think is right. There is no place for "yes" men in a properly managed organization.

Analysts and observers must be self-confident. This does not mean that they should bluff. If they give the appearance of knowing what they are after and if they go about their duties in a business-like way, a lack of knowledge of certain details should not lower them in the eyes of the workers and foreman. Most workmen enjoy explaining the fine points of their work to an appreciative listener. As much information as possible should, however, be secured from the files in the office and from direct observation. "Lighting one question on the end of the other" should be avoided, especially if the answers to many of the chain of questions are obvious.

Observers and analysts, especially the latter, are hired for the ideas they can furnish. Strangely enough, management does not particularly care if the ideas brought in by the analyst are credited to others. If the analyst is to continue making improvements, he must have the cooperation of the operators—he cannot long impose upon others his own ideas for making improvements. A program of work simplification must enjoy the full participation of all if it

is to continue very long and the best way to insure such general participation is by giving full credit to the suggestor for every idea used.

Above all, analysts and observers should not become involved in shop politics, take sides in feuds, express sympathy concerning grievances, or be guilty of passing along plant gossip. It is one thing to be friendly and another to be chummy.

CONFERENCES WITH SUPERVISORS.—After the standards department has been organized and its initial staff has been selected, it is well to inform the supervisory force concerning the new program. Form letters, circulars, and bulletin board announcements are cold, impersonal, and ineffectual. The writer was greatly impressed by the practice followed by a Chicago firm for which he once worked. He was hired as a checker, the lowest rung on the standards department ladder, but nevertheless, he was taken on a tour of the plant by the production manager and given an introduction to each foreman. This procedure should be followed with respect to every new member of the standards department. If the man who makes the introductions is the top official of the plant, the prestige of the standards department will be enhanced and it will indicate that the management is solidly behind the program.

One of the first acts of the new head of the standards department should be to arrange for a meeting of supervisors and members of his department at which the general manager should introduce and explain the time- and motion-study program to the supervisory force. If the supervisors do not understand what is going on in their departments, they will be indifferent, suspicious, or even resentful, and their attitudes will inevitably be disclosed to the workers, with a consequent handicap which the analysts and observers will be compelled to overcome. This meeting should be the first of a series of motion-study conferences at which the supervisors are allowed to participate actively in the plans for simplifying manual operations in the plant. Higher operating officials, also, should be encouraged to attend and participate in these conferences.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. "Before a successful time- and motion-study program can be inaugurated it is necessary to have a clear understanding with management as to what is involved." Make a list of the most important matters that should be settled before the program is begun.

2. What difficulties would very likely arise as a result of starting a time- and motion-study program before management has agreed:

   a. That it is not a mere speeding-up device?

   b. That the program shall be properly introduced to supervisors and workers?

   c. That workers shall not be discharged as a result of improved methods?

   d. That savings resulting from the program shall be equitably shared with the workers?

   e. That standards are not to be cut without *bona fide* changes in operations?

3. How can time and motion study aid:

   a. The office manager?
   b. The cost accountant?
   c. The sales manager?
   d. The designing engineer?
   e. The safety engineer?
   f. The rank and file worker?
   g. The foreman?

4. The head of the standards department usually is classed in the table of organization as a staff officer. How does this affect members of his department in their contacts with workmen?

5. The general manager of the Blank Corporation has issued instructions to the standards department to the effect that time-study observers are not to speak to workmen while timing them. What do you think of this order?

6. The works manager of the Western Manufacturing Company told the head of the standards department: "It is necessary for us to have time standards, but the workmen do not like to be timed; therefore, your observers will have to get standards without the knowledge of the workmen." Discuss the implications of this statement.

7. A standards department head tells his observers: "If workers ask about standards, temporize or change the subject. It is none of their business what the standards are." What do you think?

8. Comment briefly upon the attitude the observer should take in the shop toward:

   a. Male employees.
   b. Female employees.
   c. The foreman.

d. The superintendent.

e. The worker selected for observation.

9. Distinguish carefully between self-confidence and bluffing. Why should the standards employee cultivate the former and avoid the latter?

10. *Why is it important that the supervisory staff be trained in* time- and motion-study principles before observers and analysts are sent into the plant to make studies?

Chapter 4

EMPLOYEE COOPERATION

It is assumed, in dealing with the problem of gaining the cooperation of employees, that the time- and motion-study program has been properly introduced to the managers of the organization. It should never be necessary for a motion-study analyst or a time-study observer to break down prejudice against the system, prejudice which exists because of lack of knowledge concerning it on the part of supervisors and workmen. Before the standards department can ask for and expect to obtain cooperation from the workers, it is necessary that management shall have gone at least half way in demonstrating its loyalty toward the employees. To expect beneficial results from a program of economy before the supervisors know what is involved, and before they are ready to cooperate to the fullest extent, is to expect miracles.

CONFERENCES WITH EMPLOYEE REPRESENTATIVES.—Concurrently with the conferences with supervisors a series of similar meetings should be arranged with union representatives, shop stewards, or, if the plant is not organized, with representative, or key, employees. The plans of the standards department should be thoroughly explained at these meetings, and an opportunity should be given those present to ask questions. Many of the obstacles mentioned previously will be encountered at these meetings. The leader of the conference must avoid the appearance of impatience with the questions of the supervisors and workmen, many of which will reveal the presence of suspicion. It must be kept in mind that if the work of the department is not sold to most of the members of the organization soon after it is initiated there is little use in continuing.

Employee cooperation is particularly necessary at three

points: (1) in working out improved methods; (2) in putting improved methods into effect; and (3) in securing time standards. The cooperation required from the operator in making time studies is the least important of the three; it consists chiefly in answering a few questions concerning the job being timed, in providing a fair demonstration of as many cycles of the job as may be necessary to obtain a good average time for each operation involved, and in refraining from trickery designed to mislead the observer into allowing more time than should be included. On the other hand, the cooperation required of employees when operations are being improved and when operators are being trained takes an active, energetic form.

IMPROVING METHODS.—An important management device for obtaining ideas for improving operations is found in the suggestion-box system.[1] Workers usually will not submit ideas for labor-saving devices if they feel (1) that someone will lose his job as a result of their use, (2) that an idea, when put into effect, will result in more profits for the company but none for them, (3) that an idea might be rejected and later used without proper credit being given, or (4) that they will have to change their methods of working and produce more units at the same daily wage. A well-run suggestion-box system provides sufficient incentive to encourage a flood of money-saving ideas, provided the suggestions are fairly and impartially evaluated and paid for, and provided labor is not disgruntled because of bad conditions in the plant. Workers not only want a check for a good money-saving suggestion, but they are human enough to enjoy having the idea publicly recognized. The worker who gets his name, and possibly his picture, in the company magazine or on the bulletin board will feel well rewarded, and such recognition is certain to stimulate further thinking, not only on his part but on the part of his fellow workers, as well.

Assuming that the suggestion-box incentive to job im-

[1]See Taylor, E. S., "Thousands of Employee Ideas Increase Operating Efficiency," *Factory Management and Maintenance*, October 1942, pp. 106-108, for a description of an effective suggestion-box system—that of The Pullman Company.

provement is present, that the supervisory force understands the principles of work economy, and that management is intelligently cooperative and sympathetic—what is left for the analyst to do in order to obtain the indispensable help of the workers? Motion-study analysts must be liked and respected by the workers. Analysts, coming as they do in close daily contact with the workers, soon become well acquainted with a large number of individuals in the organization. They hear of petty quarrels and jealousies, they hear gossip, and often they learn about broken shop rules, impending union demands, thefts of valuable materials or tools, and other matters in which management would be interested. That serious matters in which management is vitally interested should be reported goes without saying, but it should be remembered that analysts are hired to stimulate improvements in work methods, not to act as stool pigeons. Tale-bearers are not respected, either by management or workers. The analyst who attends strictly to his business—the improvement of operations—and who sincerely tries to make things easier for the employees will be liked and respected. Such an individual is most valuable to management.

In developing better methods it is essential that the interest of the worker be aroused. This usually can be done by listening carefully to his ideas and by trying them out if they have any merit. The interest of the worker can be enlisted, also, by an explanation of what the analyst is trying to do. While the mechanical aspects of the project will probably be of considerable interest to the worker, it is well to discuss with him, and to take into consideration, his likes and dislikes as well as matters affecting his safety, health, and comfort. These matters were ignored to a considerable extent by most of the followers of Taylor and Gilbreth. Because such phenomenal results accrued from the application of the new principles (minus their human aspects) it was assumed that workers should be treated no differently than the machines, materials, and tools were treated. Had the operators been considered as being human, instead of merely part of the scenery, even more astounding results would have accrued, and, in addition, there would

not have resulted the revulsion of feeling against time and motion study which came about because of its misuse.

The analyst should treat the workers as individuals. *Although broad generalizations can be made concerning the types of response human beings show under various kinds of stimuli, such generalizations are of little value unless the characteristics of the individual are taken into account.* The analyst, in working upon various projects throughout the plant, will note that one person will cooperate because he likes the analyst and enjoys working with him, another cooperates because he feels honored to be selected as a partner in the project, another because he has certain ideas which the analyst seemed to feel could be developed and he is anxious to appear before his fellow workers as one who knows something, another because he wants above all to rise in the organization and he believes that having the reputation of being one who cooperates will not harm his chances for promotion, another because he hopes to win a suggestion-box award, another because he hopes to secure an increase in wages, another because he is afraid not to, etc. Whatever stimulus is lacking usually can be supplied if individual cases are sufficiently understood.

Small groups of workers, if led properly, can think of ideas for improving operations which could never originate with individuals. Conferences of employees are useful not only as means of stimulating thinking but as means of bringing about the correct attitude concerning the motion-economy program. The enthusiastic cooperation of a few members of the group is contagious, so by bringing together the right proportions of cooperative and non-cooperative elements, it is possible to attain a gratifying degree of collaboration among the employees.

A useful device for breaking down in advance the tendency toward resenting criticism of his methods is to encourage workers to criticize methods used by a demonstrator, either in person or in motion pictures. It is easier to see what needs fixing in one's neighbor's yard than in one's own. In going over the objectives of motion economy and the possible means of attaining them in connection with jobs other than his own, the worker is not so apt to

be blinded by prejudice. Later he can be led around to constructively criticize his own methods.

The necessity for giving all employees credit for their *ideas cannot be stressed too much, and it is mentioned again because of its importance in bringing about a proper* spirit of cooperation between the standards department and the employees.

Workers can be induced to think of their jobs in a constructive way if the importance of job improvement is kept before them continually. The appeals must, however, be varied to be effective over a very long period of time. These appeals are limited only by the ingenuity of the head of the standards department and his advisers. Cleverly drawn posters are effective in keeping the story of motion economy continually before the employees. Such posters should be replaced every month or two, so as not to weaken their force. The Plomb Tool Company of Los Angeles has issued a booklet entitled *These Are Your Weapons*,[2] which includes an illustrated check list of fourteen ways to increase production. Designed to be read by their employees, it abounds in humorous cartoons, to catch the eye, and serious photographs illustrating likely ways of avoiding unnecessary and fatiguing motions.

EMPLOYEE TRAINING.—Methods of training employees have a profound effect upon their "cooperativeness." A frequent statement made by students of time and motion study is, "I can understand how the improved methods are worked out but what I want to know is how to make the worker change to the new method." If the worker is treated as part of the machinery and is told by his supervisor, as is often the case, "You do as you are told, let me do the thinking for both of us," the analyst will have a problem when it comes to changing to improved methods. If management, on the other hand, treats the employees as partners in the development of new methods, there will be little trouble in putting improved methods into effect. An employee who has been imbued with the desire to improve existing methods of doing work, and who devises jigs, fix-

[2]By White, Howell N., Jr., and Trevor Gardner.

tures, special tools, bins, drop-delivery devices, etc., will not have to be urged to change his work habits as new methods are developed. Presumably the new methods are easier to perform, and a further impetus in the form of increased piece-work or bonus earnings should be provided to insure that management and labor, alike, will benefit from the change.

New employees are likely to stay longer if they are properly introduced and trained; certainly they will be happier on the job. Proper training includes six steps:[3] (1) Explain to the new employee the importance of the job to the process as a whole and to the company; (2) explain what to look for in the demonstration which is about to be performed; (3) demonstrate the proper method of performing the job *at the proper tempo;* (4) ask for questions from the beginner; (5) allow the beginner to perform the operations, insist that he perform them at normal tempo, and point out his mistakes; and (6) follow up, frequently, to see that the job is being done properly.

A vision of the importance of the operation provides an incentive which wages alone can never furnish. Any mystery surrounding the job causes the new worker to become ill at ease. Whether it is expressed or not, the first question that arises in the mind of the operator, after he is shown his workplace, is: "Why is this work performed?" Sometimes the answer is more or less obvious; more often it must be found by quizzing associates—and this the new worker is reluctant to do. New workers should be taken through the plant and given an opportunity to view the processes from start to finish. They should be told something concerning the origin of the raw materials and the destination of the finished goods. Such information not only arouses interest but creates in the new worker a feeling of responsibility which has a profound effect upon the quality of the work which he subsequently does. Even office workers are curious about the products made by their concern. The writer was taken on a tour of one of the great West Coast aircraft plants. As he entered, the usual wartime pre-

[3]We are interested chiefly in training on the job, and not so much in apprenticeship training or vestibule training.

cautions of signing, fingerprinting, and tagging were taken by a young lady in an outer office. At the conclusion of the tour she asked if the trip had been enjoyed, and added wistfully: "Gee, I wish I could go through the plant." She had been sending visitors through for over two years and had never been permitted to set foot, herself, inside the plant!

To return to the new worker, he is about to view a demonstration of his new job. He is anxious to make a good impression. The demonstrator performs the sequence of operations in rapid order, then asks the new worker if he understands everything. Almost invariably the answer is "Yes," or "I think so"; rarely does the new worker tell the truth and say "No." He is afraid the trainer will make some such rejoiner as: "I thought you were an experienced worker"; or "My, but they're hiring dumb people these days." He would rather run the risk of doing the job incorrectly than to admit at the outset that he did not understand the demonstration. In spite of the vital importance of a careful explanation of what to look for in the demonstration, this step is frequently overlooked. The writer emphasizes to his students at the University of California the importance of this step by performing one or more sleight-of-hand tricks in front of his classes. Although an industrial operation is not a sleight-of-hand trick, it often seems like one to the learner. Few observers are able to repeat the simplest trick, unless they have been told what to look for in advance.

In demonstrating the proper method, it is important that the sequence of motions be performed up to tempo, or at the speed at which normally skilled operators normally work. One reason for this is that the demonstrator unconsciously changes his methods when he slows down. Another reason is that training on the job often involves the use of machinery or it often takes place on a production line, where it is impossible to go slowly at first and pick up speed as skill is acquired. If the operator must observe the operation at a slower speed, in order to understand its intricacies, a happy solution involves the use of motion pictures. Pictures made of a skilled operator working at full speed can be slowed down, or even run backward, without

the disadvantage of the changes in method which almost always follow changes in tempo.

Giving the beginner a chance to ask questions is better than asking him if he understood the demonstration. It gives him a chance to clarify the many uncertainties which always beset the neophyte. Usually one of the questions is a request that the demonstration be repeated. There is, of course, no objection to this, nor to the repetition of any of the other five steps.

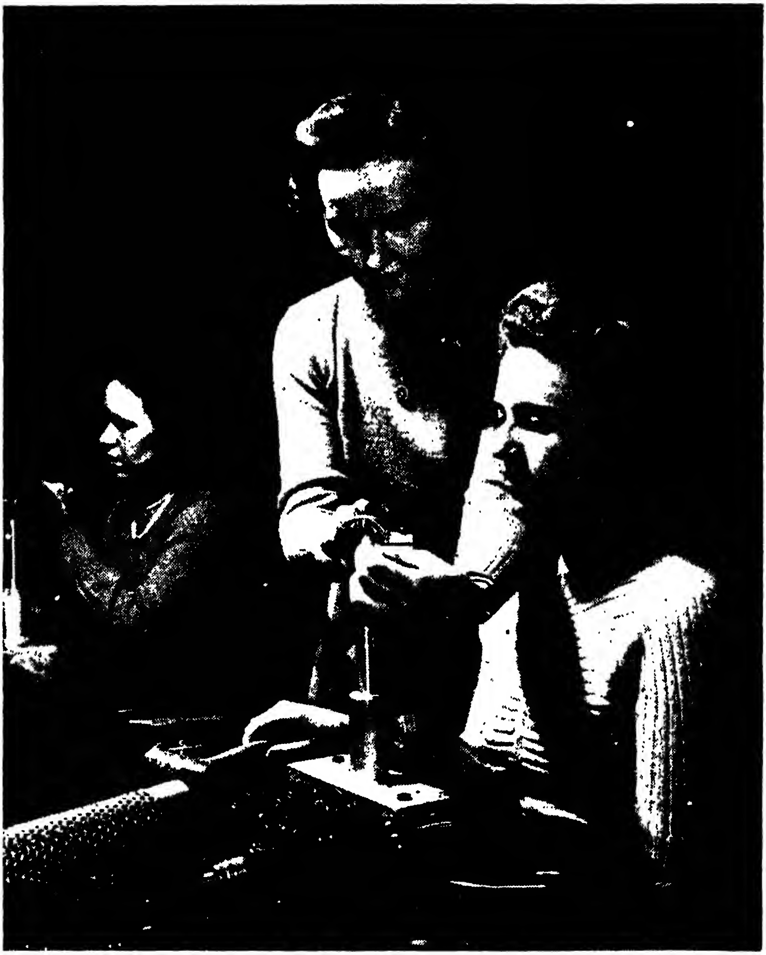
Next, the beginner should be tested; in other words he should be asked to repeat the demonstration at the normal tempo. For some reason there seems to be considerable objection among students of industrial management to the theory that beginners should work at the speed of experts. Such students insist that the practical realization of such a dream would be broken machinery, spoiled materials, and injured workmen. These objections are well taken, and it must be admitted that situations exist which are exceptional. On the other hand, the hazard to limb and property usually is *less* when the job is performed at the proper speed. It is harder to keep upright on a bicycle if the forward motion is slow than if it is rapid. It often is objected that a complicated sequence of operations cannot possibly be repeated up to speed the first time, and typing is cited as an example. But, strangely enough, typing is now taught with the emphasis placed upon proper method and speed. The old system of teaching involved typing a sentence about a lazy fox jumping over something, a sentence which included every letter in the alphabet. The beginner was supposed to repeat this sentence very slowly until he learned the positions of the letters and keys, then he was expected to pick up speed. The objection to such a system is that in the desire to learn accuracy first, method has been subordinated, and by constant repetition of the sequence of motions at a slow tempo, wrong work habits have been formed. When, later, it is desired to work up to normal tempo, the old work habits must be broken and new ones formed. The truth of this becomes apparent when viewing motion pictures of an operation performed slowly and rapidly. As a rule the methods differ under varying conditions of speed.

The modern method of teaching typing is to start with a simple word and practice typing it at normal speed. Under this system speed and method are kept constant, while complexity is varied. Some operations, however, require that all three must be kept constant. The machine operator on a production line cannot perform a simple, fractional part of the job, nor can he slow down the operation. Workers who break in on such jobs frequently already possess skills of a kind which enable them to learn quickly without disastrous results. If, however, the operator is completely unfamiliar with the new job he is trained somewhat like the motorman, engineer, or airplane pilot. The writer learned to fly in an airplane equipped with dual controls. He was told to hold the throttle and the joy stick lightly so as to get the feel of the controls while they were being manipulated by the instructor. The airplane flew at standard speed; there was no slowing down for the beginner. When speed, complexity, and method are all kept constant, an instructor must be present to help the learner, should he get into difficulties.

The sixth, and last, step involves periodic checks. It is necessary to follow up at intervals the methods of the learner until the trainer is sure correct work habits have been formed. These intervals will become progressively greater for each worker who makes satisfactory progress.

The principles of time and motion study can be taught to employees in any one or more of a number of ways: by means of company-managed vestibule schools, the use of skilled workmen on the job, special instructors in the plant, or by sending them to extension courses taught in university schools of engineering and business administration. Many methods, or techniques, of teaching are available, including lectures, conferences, demonstrations, quiz and problem contests, posters, pictures in company papers, motion pictures, slides, instruction sheets, and booklets.

Vestibule schools are of value only for teaching techniques which are used by a substantial number of employees in a given plant, as well as such things as the policies, rules, etc., of the company. Inasmuch as the basic principles of time and motion study can be used in some degree



Courtesy of General Electric Co.

FIG. 2—*Trainer demonstrating to a beginner the proper method of performing a job.*

by all employees, the vestibule school seems to be the logical place to begin such training.

In using skilled workmen to teach new employees "on the job," care must be taken to find one who knows how to

teach. A common failing in skilled workers is that they are impatient with beginners.

The use of special instructors should be confined to lectures, demonstrations, motion pictures, and lantern slides. An outsider who comes into a department and tries to tell the workers how to perform their jobs, generally meets with stiff resistance.

It is advisable to combine as many as possible of these methods and techniques in the training of each individual for the reason that the worker who hears about time- and motion-study principles from only one source and does not have pressure brought to bear from any other source tends to discount much of what he learns, or he may even openly scoff at the new information. For instance, the worker who is urged by his supervisor to take a university extension time- and motion-study course may (if the management at his plant provides no method of following up and assisting such students in applying what they learn) take the attitude that "time and motion study may work elsewhere but its principles can't be applied here."

It will be agreed that much of the time of the head of the standards department should be employed in training activities. It is not enough to develop methods and time standards—the entire organization, management and workers alike, must cooperate in developing methods and time standards. Unless a well-rounded and coordinated program is instituted and vigorously pushed the standards department will realize only a small fraction of its potentialities.

FINANCIAL INCENTIVES.—Over a long period of time, sustained interest of employees can be successfully maintained only by providing effective incentives. The most powerful combination of incentives includes: agreeable and safe working conditions, skillful and fair management, a chance to get ahead in the organization, reasonable security of tenure, recognition for work well done, and a wage-payment plan which closely links remuneration with performance and which provides higher wages for increased responsibility as well as for increased production. The head of the standards department can do much to encourage the introduction of all of these factors.

The wage-payment plan, which it is proposed to discuss in some detail, should recompense the old operator who is asked to change to a different method of performing a job, not only for the discomfort engendered by the necessity of forming new habits of work and breaking old ones, but for possibly temporarily lowered income during the learning period. We know that new methods must be introduced with tact and persistence. Although most people would listen to a plan that would make their work easier (unless they lost face by adopting the new plan), a worker is frequently found who actually enjoys performing work in an inefficient manner, not because training and habit patterns have conditioned him to that way of working so much as that he gets pleasure from working himself through a particularly difficult set of conditions. In these people the activity itself is closer to their consciousness than the end result or accomplishment of the activity. The need for dealing with the almost insuperable difficulties represented by these, and other cases, involving the introduction of improved methods of performing factory and office operations can, for the most part, be avoided by the introduction of a good financial incentive system.

The financial incentive system should not be selected by management and imposed upon the employees by proclamation, as is frequently done. The standards department will have considerably less trouble setting standards if the employees have had a chance to thoroughly understand the proposed system before it is put into effect. This can, in most cases, be accomplished through meetings of employee representatives and by issuing printed descriptions with plenty of clearly worded illustrations.

Much has been heard concerning the objections of unions to incentive systems, the desire on the part of union members to reduce efficiency, and the union rules which limit production. All unions are, however, not alike in this respect. The following quotations could well be taken from a management manual: "To make the work go at top speed it would be well to arrange for a plant committee . . . ," "Keep your eye on the ball—increased production . . . ," "Carefully study the following section—it will show what

can be done to increase efficiency." These quotations are taken from *Producing for Victory, A Labor Manual for Increasing War Production,* published by a union for its members.[4] This manual includes sections on increasing the productivity of labor, increasing the productivity of equipment, effective use of materials, and effective controls.

Unions have for many years cooperated with management to the extent of jointly retaining the services of independent time-study observers for the purpose of setting impartial time standards and piece-work rates. *Production Standards from Time Study Analysis* is the first time-study manual to be prepared jointly by a business concern and a union. It was prepared under the direction of a firm of management consultants by union time-study stewards of Local No. 2 U.A.W.-C.I.O. and The Murray Corporation of America, Detroit.

Many union members who in the past have violently opposed time and motion study and incentive systems are now clamoring for them, because under federal anti-inflationary legislation they form a means through which labor's income may be increased. Manufacturers are allowed to pay more to workers who produce more. In most cases, very likely, labor's objections to the use of time and motion study have resulted from the misuse of principles which *per se* are fundamentally sound.

A TYPICAL WAGE INCENTIVE SYSTEM.—The installation of a wage incentive system that is considered to be fair to both management and workers is illustrated as follows:

After the system is accepted by representatives of management and labor, and assuming that the operations have already been studied and improved, one or more departments are chosen in which to make time studies. A checking system is established which permits the exact time and amount produced to be determined for each job performed by each operator. The checker reports this information daily by operators, or by gangs if individual productivity cannot be determined. Next, a systematic procedure is fol-

[4]Prepared and compiled by International Federation of Architects, Engineers, Chemists, and Technicians; published by the Congress of Industrial Organizations, 1942. See pp. 13, 15, and 26.

lowed of establishing time standards for every operation performed on each product as well as for certain indirect operations which can be checked readily. As the standards are completed and submitted to the head of the standards department, he satisfies himself that they are correct by comparing them with actual productivity as shown on the daily checkers' reports. When a substantial proportion of the operations are standardized the standards are submitted to the joint management-labor committee, which approves each new standard and each standard change, and finally, approval is given by the superintendent of the plant. When approval has been granted to the initial batch of standards, the department is said to be "on standard," and thereafter the checker inserts opposite each production figure its corresponding standard for the purpose of calculating each operator's bonus for the day.

Not all jobs in a department which is "on standard" need to be standardized; those which are not, are known as "day-work" jobs. Such jobs are shown by the checker, the time and amount produced are shown, but obviously no standard is inserted. Such jobs usually are present in every department and represent (1) jobs which the observers have not yet had an opportunity to study, (2) temporary jobs which it would not pay to standardize, and (3) jobs on which it is difficult or impracticable to check productivity. Individuals who change from day work to standard jobs must be checked carefully, for one who is reported as being on day work an hour during the day, but who actually was on standard, will get the advantage of what he produced during that hour, but the time will not be charged to him.

The checker's daily report for five operators of a given department is illustrated in Figure 3.

Operator No. 101 illustrates the worker whose eight-hour achievement exactly equaled what the standard required. The standards are so expressed that when they are multiplied by the amount actually produced the result expresses normal, or standard, time. The first operator punched 10,000 1″ blanks on machine No. 16A. The standard, which is .080 hours per 100 pieces, when multiplied by 100.00 gives 8 hours. This normal, or standard, time is 100% of

CHECKER'S REPORT

Department A

Date: Sept. 20, 19--

Pay roll No.	Description of Operation	Machine Number	Standard Number	Production	Units	Standard	Standard Hours Produced	Hours Worked	Percent Efficiency	Hours Saved	Hours Wasted	Base Rate $ Per Hr.	Bonus Earned $	Day Work
101	Punch 1" blanks	16A	N-10	100 00	Pcs	080	8 00	8 00	100	0	0	70		
102	Punch 1" blanks	16B	N 11	150 00	Pcs.	075	11 25	8 00	141	3 25		70	2 28	
103	Punch 1" blanks	16C	N-12	95 00	Pcs	080	7 60	8 00	95		40	70		
104	Punch 3" blanks	16D	N-13	80 00	Pcs.	100	8 00	5 00	160	3 00		70	2 10	
	Oil Machines													3 00
105	Punch 1" blanks	16E	N 14	40 00	Pcs	085	(3 40)							
	Punch 3" blanks	16D	N 13	38 00	Pcs.	100	(3 80)							
							7 20	5 00	144	2 20		70	1 54	
	Sort tin													3 00

FIG. 3—*Checker's report illustrating the use of time standards for a wage incentive system.*

the time actually worked by the operator, so 100 is placed in the column headed "Per Cent Efficiency."

Operator No. 102 is a good producer. 150 lots of 100 pieces each, multiplied by the standard, .075 hours per 100 pieces, yields a normal time of 11.25 hours. This time is placed in the column headed "Standard Hours Produced." A better description would be "Standard Hours' Worth of Work Produced." If the operator had worked at a normal speed, 11.25 hours would have been required to complete what actually was produced in 8 hours. 3.25 hours have, therefore, been saved for the company, time which might have tied up another machine, used up power, light, and heat, and required supervision, as well as all of the other overhead items chargeable to that particular order. Since the company has saved at these points and would like to encourage further savings, a bonus amounting to 3.25 times the operator's hourly rate of pay (70 cents) or $2.28, is paid to the operator.[5]

The third operator, No. 103, has had a bad day. According to the report, 7.60 standard hours were produced in 8 clock hours. Since 7.60 is 95% of 8, the operator was only 95% efficient and 0.40 hours were wasted. No bonus is paid for the day's work. This operator draws pay for 8 hours, however, at the rate of 70 cents, a total for the day of $5.60. This is the same amount of base pay drawn by each of the five operators used as examples.

The next operator, No. 104, is either a super-expert punch-press operator or else a mistake was made by the checker in apportioning the hours on standard and on day work. According to the report, 8 standard hours were pro-

[5] In this example the operator is paid for all of the time saved. Similar wage incentive systems frequently provide for the payment of something less than all of the savings—some systems going as low as half. Two reasons which justify the employer in not paying the employee for the entire saving are (1) if a substantial number of operators fall below 100% efficiency the employer is penalized, for he pays the minimum hourly rate for less than normal output and (2) the cost of installing and maintaining the wage payment system (the employer might argue) should be paid out of the savings that result, part from the savings in overhead and part from the bonuses that otherwise would be paid to labor. This is a point which bargaining can settle in each case.

duced in 5 clock hours and 3 hours were spent oiling machines. Had the operator actually spent one of these hours operating the punch press, 2 hours instead of 3 would have been saved and the bonus should have been $1.40. This illustrates the importance of carefully checking time as well as pieces produced.

The last operator, No. 105, worked on three different jobs, two were on standard and one was day work. It is essential to keep the amount produced on each machine separate, for each machine may operate at a different speed with a different standard. Once the standard hours have been found for each machine they can be added. It is not necessary to keep the clock hours separate for each of the jobs performed on standard, though this is sometimes done for purposes of closer checking in order to minimize the chances of error. It is essential, of course, that the time for sorting tin (day work) be kept separate from the time spent operating the punch press (on standard).

It has been objected by some that an incentive system, such as that described, substitutes exact standards for bargaining, and tends to prevent workers from increasing their wages as their bargaining strength increases. It is true that the standards should not be made a subject of bargaining. There is nothing wrong in asking a time-study observer to justify one or all of his standards—but this is not bargaining. Once the time standards are set and put into effect they should not be changed except for significant changes in the method or machine speed or to rectify obvious mistakes. Legitimate points where bargaining may take place are the hourly base rates and the division of the savings.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. An analyst accidently walks into a dice game during working hours. Should he (1) express disapprobation, (2) turn his head and pretend not to see anything, or (3) join the game? Should he report the incident to the foreman or ignore the matter? If he ignores the matter, to what extent will the cooperation he receives in the future

from these employees be influenced (1) by fear, (2) by a feeling of reciprocity, or (3) by a feeling of friendship?

2. What is wrong with this situation: Top management retains a consultant to make methods improvements in the plant. The foremen concerned are notified that the consultant and his men will work in the plant and that they are to give them their fullest cooperation. You are one of the consultant's assistants. What personnel difficulties can you expect? Would you be surprised at trouble (or, at best, passive resistance) from the supervisors? How might the workers react?

3. Describe what you believe to be a good employee suggestion system. Under what conditions will workers refuse to submit labor-saving ideas to management?

4. What do you believe to be the most important considerations in gaining the cooperation of workers in working out improved methods?

5. How can you get a worker to accept, without resentment, criticism of his own methods?

6. How would you go about getting a skilled workman to change from methods he had used for years to a new way of working? How can you keep him from "losing face" when he changes? Is it possible for him to avoid "losing face" if each of you previously has committed himself to opposing sides in an argument?

7. What six steps should be followed for best results in training employees on the job?

8. What precautions should be taken before the trainer demonstrates to a beginner the proper method of performing a job?

9. Discuss the arguments for and against training beginners to work at normal tempo from the start.

10. Why is it desirable to put a wage incentive plan into effect in connection with a time- and motion-study program?

11. What are "day-work" jobs? Why is it just as necessary to check the time spent on them as it is to check the time spent on jobs "on standard"?

12. Why should the entire organization participate in the time- and motion-study program?

13. Can collective bargaining be carried on, where financial incentive plans are in effect, without requiring accurately set time standards to be changed? Explain how.

PART II

THE PURPOSE OF THE OPERATION

Chapter 5

NECESSITY FOR THE OPERATION

The subject matter of this book is arranged for the most part in the order in which a standards department head would work if he had the time to do a thorough job. The logical order in which a permanent program of time and motion study should be carried out would work from the most general aspects of the problem down to particulars, i.e., from a study of the purposes of the concern as a whole, through those of each department, down to a study of the purpose of each operation. Layout should be studied, first, in the plant as a whole, then by departments. The last group of studies should consider the motions of individual operators, with the attendant problems of material handling, the use of jigs and fixtures, the correct tools, improved bench layout, and finally the determination of time standards for each element of each job studied. The logic of this order can, perhaps, be appreciated fully only after the reader has completed the book. One illustration will, however, indicate what a reversal of this order might mean. Assume that an entire department is processing (shaping, cutting, drilling, painting, etc.) an antenna rod for an airplane. If time studies were made first, they probably would be tentative only; "final" time standards are established only after all improvements on essential operations have been put into effect. If motion studies were made next, each operator's motions would be analyzed, the best would be selected, better arrangement of workplaces would be studied, improved tools would be developed, bins and drop-delivery devices would be built, conveyors and chutes would be put in, the workers would be re-trained in the improved methods—in short, considerable time and money would be spent and, it is assumed, savings would result. But,

in passing from particular to more general problems, it could well be that each successive step would cancel out most or all of the benefits which had been realized from the previous work that had been done. A subsequent methods study might indicate that part of the processing could be eliminated. If so, the detailed studies of motions used by those operators whose jobs would be made obsolete would have been made in vain. A subsequent plant layout study might render the material-handling system obsolete and the entire department possibly would have to be moved so as to put it into harmony with the plant as a whole. And last, a study of the purpose of the operation might indicate that a projection on the fuselage made of a more easily worked material would serve the purpose just as well—thus making the work of the whole department unnecessary. Had this fact been discovered *first*, much time and fruitless effort would have been saved.

WHAT IS AN UNNECESSARY OPERATION?—Whether a particular industrial operation is or is not necessary depends upon one's viewpoint or attitude, and upon certain assumptions. For instance, it might be said of the operation "inspect tin blanks" that it is necessary because (1) the punch press is defective, (2) the die is defective, (3) the tin plate is spotted with rust, (4) the tin plate was not slit properly, or (5) the punch-press operator is unreliable. The foreman might take the viewpoint that this inspecting operation is necessary if reasons (1) or (3) were causing the extra work, for the purchasing of machinery and materials is done by others, and rectifying the wrong conditions is beyond the scope of his responsibility and authority. On the other hand, the foreman very likely would hold that the extra inspecting job was unnecessary (provided he gave an honest opinion) if it were caused by a defective die, improperly slit tin plate, or an unreliable or improperly trained operator, since these are factors that are within his control. From the viewpoint of the person doing the inspecting, the job might well be considered necessary, for that person would probably neither know nor care about the conditions which gave rise to the extra work. It is a rare worker, indeed, that investigates his own

job and makes recommendations to his superiors which, if carried out, would serve to abolish the job.

In asking the question, "Is this department necessary?" or "Is this operation necessary?" a long-range viewpoint should be assumed. From such a long-range viewpoint it is obvious that this inspecting operation is just so much waste motion. A person with a long-range, or plant-wide viewpoint, if asked concerning the necessity for inspecting tin blanks, would reply that the operation would be unnecessary if certain other conditions were right. There are two kinds of unnecessary jobs: (1) those introduced to correct an error made elsewhere in the organization and (2) those which have become obsolete because of evolution in the plant methods, changes in the design of the product, or for other reasons, and which can be abolished without any other change or without affecting other existing operations, but which continue to be performed because the supervisor does not know that the job no longer needs to be performed. The first type will be called provisional jobs and the second, superfluous jobs.

PROVISIONAL JOBS.—Jobs which are made necessary because of an error committed elsewhere in the organization are fairly common. They exist for a variety of reasons, but chiefly because no coordinating authority exists in the organization for the purpose of tracing such operations to discover why they are performed. This is one of the most useful functions of the standards department. The purpose of every operation is questioned by this department and nothing that is being done in the plant is taken for granted.

Time-study observers are expected to question the purpose of each operation they standardize and satisfy themselves of its necessity before making the study. Most observers can easily spot a superfluous job, but it often requires considerable persistence and ingenuity to detect the provisional jobs. Often these jobs are made necessary because of an error in judgment on someone's part. But whether or not the extra operation is justified can be determined only after considering the case from all angles. For instance, a good customer ordered a cylinder of ammonia from a compressing plant and insisted that it be de-

livered on Saturday afternoon in order to prevent a shutdown of his refrigeration system and a consequent spoilage of food. The plant had to hire an outside truck and driver, and pay costs amounting to about ten dollars to deliver a cylinder on which the profit would have been fifty cents had it been delivered under normal conditions (with a full load and on a regular delivery day). Considering the delivery from a broad standpoint the operation perhaps was not unnecessary, for it kept the goodwill of a customer. But the motion-study analyst might consider such a delivery (especially if there were many of them) as being due to the negligence of someone who probably could have prevented it and still have kept the goodwill of the customer. This illustration indicates something of the controversial and delicate nature of the problem of detecting provisional jobs.

The man responsible for buying materials often is responsible for provisional jobs. Several carloads of tallow were purchased at a bargain by a soap plant. Since storage space indoors was insufficient to accommodate the entire shipment many of the barrels were stored on planks in the yard. The extra handling made necessary by the unusually large quantity purchased constituted the provisional job. Acts which make such jobs necessary are justifiable as a rule only when the saving in cost of materials exceeds the cost of the provisional job.

A provisional job resulted from an error when an order for cartons was placed. The sample carton was made up in the art department and forwarded, with the approval of the general manager, to the purchasing agent who ordered a large quantity. After they were received it was discovered that they could not be used in the automatic carton-filling machinery due to the fact that all of the flaps were of the same length. These collapsed cartons are placed in a magazine from which they are withdrawn, opened, glued, and filled automatically. They are withdrawn and opened by a thin steel wedge which must clear the first flap and slide up inside the collapsed carton, and in order to do this the first flap must be shorter than the others. Rather than scrap the cartons it was decided (in

the absence of a practicable mechanical method) to cut the flaps by hand, using scissors. This was a provisional job that required weeks to finish.

Many provisional jobs are admittedly wasteful, but must be performed because someone bungled. When they are finished they are not repeated, for the erring one has been taught his lesson. There are, however, countless cases of makeshift jobs, and jobs that are thought to be necessary but which, with a little persuasion here and there, can be eliminated. A case in point is that of a machine that was supposed to feed automatically. The magazine was not adjusted properly and, as a consequence, the machine frequently jammed. After summoning the service men of the manufacturer of the machine several times, with no results, the foreman assigned two extra operators to the duty of feeding by hand, after which things went smoothly. The hand feeding continued until a time-study observer insisted that the magazine be adjusted properly, a result which was accomplished after only a few more visits from the service men.

A provisional job resulted when a manufacturer of pharmaceuticals complained of dust in the containers he was buying from a paper can manufacturer. The tubes from which the cans were made were stored in a dusty section of the plant because that was the only space available. It was thought necessary to add an operation—wipe dust out of tubes—until the storeroom was made dust tight, after which the provisional job was discontinued.

It is necessary to drill holes in unfinished airplanes for various purposes. Provisional jobs often result when the drill goes too far, puncturing parts which then must be repaired.

Occasionally a provisional job can be attributed to faulty workmanship or materials in parts purchased from outside the plant. The extra operations necessary to put the parts in proper shape often can be eliminated by changing vendors.

Provisional jobs frequently are difficult to eliminate, not so much that their causes cannot be detected and removed as that there is a tendency on the part of those who au-

thorize such jobs to insist that they are necessary. If such individuals are overruled, there is a tendency to blame anything and everything that subsequently may go wrong in the department upon the change.

SUPERFLUOUS JOBS.—Frequently it happens that a complaining customer makes it necessary to add an operation temporarily. Such operations all too frequently become a permanent part of the process. (It seems to be easier to add operations than to discontinue them.) Sometimes, too, the requirements of subsequent processes will not be understood by a foreman, who will require operations which are entirely unnecessary to be performed in his department. Instructions often are misunderstood, too, and useless work results. A case in point is that involving a complaint from a customer that tin closures were defective. They were punched from lacquered tin plate, one lot of which cracked in the process of being punched and drawn into shape. It was proposed that an extra operation—oil tin—be introduced after it was discovered that a thin film of oil applied with a cloth would prevent the cracking. This operation was performed in the tin slitting department, for the large sheets of tin could be oiled more rapidly and entailed less handling than would have been necessary after being cut into strips. Although subsequent lots of lacquered tin which did not require oiling were purchased, the operation continued to be performed until a time-study observer questioned the operation and discovered it to be useless.

Superfluous jobs often result from poor coordination in an organization. A time-study observer, for instance, was asked by a foreman to standardize a day-work job in his department, a job that involved separating large chunks of scrap soap from several cutting tables and putting one kind in dump trucks on one side of the aisle and the other kind in dump trucks on the other side. Before setting the standard the observer followed the truckers, only to discover that the two kinds of scrap were being dumped into the same remelt kettle. The foreman of the kettle-soap department had not thought to notify the foreman of the cutting department that it was no longer necessary to separate the two kinds of scrap.

Superfluous jobs are not limited to the shop; such jobs are frequently found, as well, in offices. There are countless examples of reports and statistics being compiled and filed without anyone ever looking at them. But should an observer, in trying to justify the operation of preparing a report, suggest that the work was superfluous he would, in most cases, meet with protestations that the organization might be able to get along without the report but that it would have to operate in a badly crippled condition. An interesting example has to do with a report that both the time-study observer and the office manager agreed was superfluous but which the general manager thought he needed. The full time of a girl one day a week was required to prepare this report, which had been made obsolete when the information was compiled in better shape in a new report. A day arrived when it was necessary, as a result of the press of extra work, for the office manager to postpone the "B" report, as it was called. The decision was made with fear and trembling—but nothing happened, the general manager did not miss it. A second day passed, and a third—the "B" report was dropped and forgotten, and nothing was said. One morning about five months later the whole office was startled to hear the general manager burst in, shouting at the office manager, "Where is my 'B' report? I didn't get it this week!"

Occasionally a superfluous job may be justified as, for example, in the case of "made work" provided for the purpose of keeping valuable workmen on the payroll and in the plant during temporary periods of depression—all other expedients having been considered and rejected as being less practicable than this.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What is the logical order in which a permanent program of time and motion study should be carried out?
2. Why is it that a foreman might wish to continue performing an operation which the observer believes to be unnecessary?
3. Two kinds of unnecessary jobs may be distinguished; name and give an illustration of each.

4. Which type of unnecessary job is more difficult to detect? Why?

5. American industry has a world-wide reputation for efficiency. How, then, can you explain the presence of superfluous jobs?

6. Name as many situations as you can which serve to introduce provisional jobs into plants and offices.

7. What precautions would you take and how would you go about abolishing

   a) Provisional jobs?
   b) Superfluous jobs?

8. Can the existence of provisional jobs ever be justified?

9. Do you think the example in the text of a justifiable superfluous job is valid? If you believe that such jobs are occasionally justified can you think of other examples?

Chapter 6

EFFECTIVENESS OF THE OPERATION

While studying the operation, material, and layout for possible improvements, it is essential to try to see the problem from the viewpoint of the plant manager. Proposed changes must be consonant with plant-wide plans or they will be rejected. A highly desirable change in a departmental layout might be proposed and vigorously promoted by a motion-study analyst, but if major changes in the product are contemplated by the management it is the better part of wisdom to continue for the time being under the less efficient arrangement.

IMPROVEMENT. — Time-study observers usually are not asked to standardize unnecessary operations. This, however, should not absolve them from the responsibility of looking for unnecessary elements. The motion-study analyst, after abolishing the unnecessary jobs, examines those which remain with the object in view of improving them. If preliminary analysis seems to indicate that improvements will pay, the analyst looks for evidence that certain parts of the operation may be unnecessary, i.e., that something is being done which can be eliminated by making a minor change in the product. He considers the effectiveness of each operation as it contributes to the whole.

DESIGN.—Blueprints frequently convey to the production department ideas which were not intended. If, for instance, a hole is to be drilled through a bolt and if the hole happened to be drawn parallel with a slot in the head of the bolt, it would naturally be inferred that time should be taken to align the slot and the hole. An analyst might ask the reason for such careful alignment, and, in tracing the matter back to the designer, discover that it was never intended that the hole should be drilled at any particular angle

with reference to the slot; all that was needed was a hole for a cotter pin. If the designer had shown the slot in a horizontal position and had drawn the hole at an angle with the notation: "Drill at any angle," the production department would not have been misled.

As a rule the sales department is responsible for new products and changes in old products. It is necessary, however, for this department to cooperate with other departments in developing proposed changes. The standards department often can suggest slight changes in design which materially lower labor costs. Assembly problems might be simplified, for instance, by using a slotted or a hexagonal headed bolt instead of a smooth headed bolt. Snap rings might be used instead of cotter pins. Slots might be used instead of holes. And so on. Often such minor design changes can be made without affecting in the slightest the utility or appearance of the product, and often it is surprising how much time and money can be saved as a result.

Figures 4 and 5 illustrate how relatively simple design changes can effectively reduce the expense of assembling

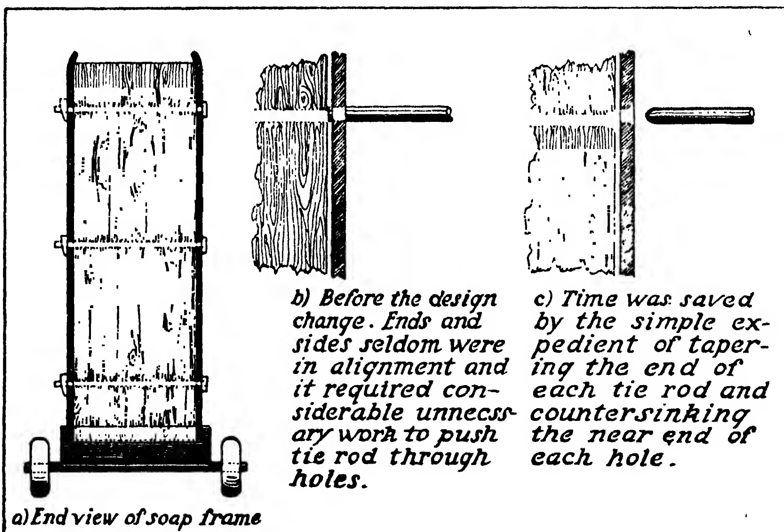


FIG. 4—*Minor design change facilitates assembly of soap frames.*

parts. A piece of equipment used in soap plants is shown in Figure 4. Molten soap is dropped into frames to harden. The sides are then removed and the soap is cut into slabs and removed from the base. The sides and ends of each frame are then re-assembled to their base and held in place by means of tie rods and wedges.

It is obvious that if the hole in the end of the frame is not lined up with the holes in the sides, the rod cannot be pushed through. It often requires considerable juggling and wasted time and effort to assemble a frame, most of which can be avoided by tapering one end of the rod and countersinking one end of each hole in each part.

Figure 5 represents a small, but important, part of the landing gear of an airplane. Four elastic washers, made of plastic material, must be slipped onto the part shown in the drawing. Each washer is hollowed out on the side which goes on first. This, in addition to the fact that the washers are elastic, made it rather difficult to get them over the shoulders xx′. The design change in (b) was suggested by the motion-study analysts who worked out an improved method of assembly. It simply involved the production of parts with sloping shoulders (yy′) instead of shoulders standing at right angles (xx′). This design alteration made no change in the effectiveness of the part; the parts could be fabricated at little or no additional expense; and the labor saving during assembly made the change well worth while.

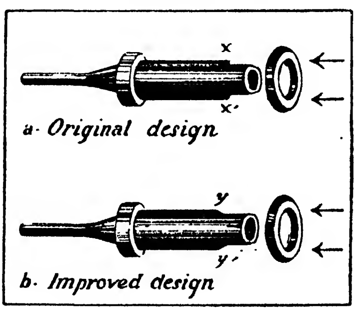


FIG. 5—*Landing-gear parts were assembled more easily after this minor design change. (Suggested by Mr. Hugh H. Boyes and Mr. Ray A. Wilson, Jr.)*

The student who has not had industrial experience may wonder how in this machine age a designer could possibly be so bad as to make mistakes that could be detected and corrected by a motion-study analyst. Strange to say, however, such mistakes *are* made, as may be seen by anyone who cares to take the trouble to investigate. That such errors in design are made can be accounted for very easily. It may be that the designer does not know the best sequence of operations that should be followed in the fabrication of the part. It may be that he is told by his employer (who may know less than the designer concerning the technical aspects of the problem) to make the product look thus and so. It may be, too, that the designer has not been fully informed concerning the use of the part; he may put extra strength where it is not necessary; he may put in graceful curves for the sake of appearance when greater strength and the cheapness and simplicity of straight lines are needed; etc. It may well be that the drawings of the designer have been misinterpreted, or have been inadvertently changed in copying. Those who have traveled in China say that it is practically impossible to obtain chopsticks (or other articles) bearing uniform designs, if the products have been made by Chinese artisans. Each Chinese not only wishes his products to differ from those of other artisans, but he wishes, as well, to show his originality by giving each piece some character of its own. American designers sometimes attempt, similarly, to show originality by working out their own designs rather than run the risk of being caught copying. But such originality often causes considerable trouble in the shop.

MATERIAL.—The analyst often suggests a more appropriate material than that being used. Such suggestions may be made on the basis of information gleaned from workers, from experience and personal observation of the results of using various materials, or by an analysis of costs. The criterion should be: what is the best material from the standpoint of the entire process? For instance, from the standpoint of the operator, brass might be a better material than steel. The worker could argue that brass was more easily worked and made a better product than steel.

But assuming that steel was selected originally because it was satisfactory from the standpoint of quality, the suggestion that brass be substituted would be rejected (1) if the price of brass was too high, (2) if it was difficult to procure, (3) if it was hard to store, or (4) if other barriers to its economical utilization were present. Those who specify the materials to be used in industrial processes occasionally are on the side of cheapness; that is to say, they do not fully consider the savings in labor and overhead which might result from the use of a material whose purchase price is high relative to the purchase prices of alternate materials. Before suggesting a substitute material the analyst should attempt to determine why the material now being used was originally specified; and, in computing savings to be expected as a result of introducing a substitute, *all* costs should be carefully compared: original prices, transportation costs, insurance costs, handling costs, storage costs, and any others that appear to be pertinent. If these costs are all greater for the substitute material, it still may be feasible to recommend a change, provided the savings to be expected in the production departments are sufficiently great; i.e., there must be a net over-all gain as a result of the change. The effect upon the market must not be forgotten, and this is often difficult to appraise. It may well be that a suggestion, which presents a clear case in favor of a substitute material, will be rejected by a conservative manager who wishes to be on the safe side. Often the substitute material will not be used, even though it is cheaper, because it does not harmonize with other materials which go into the finished product. Neither may the production manager wish to add one more to the already large variety of materials being used, because possibly, it will have to be purchased from a separate vendor with consequent trouble in contacting him and establishing the new relationship; and of course, the new material will have to be stored and accounted for separately.

CHANGES IN METHOD.—Some attention should be given to the possibility of making savings through changing to a different machine, using two- or three-station dies instead

of single dies, using more than one drill at a time (see Figure 6), eliminating drilling by coring holes in castings, eliminating tapping by using screws that cut their own threads when put in place originally, reducing planning and layout time by putting reference marks on patterns, etc.

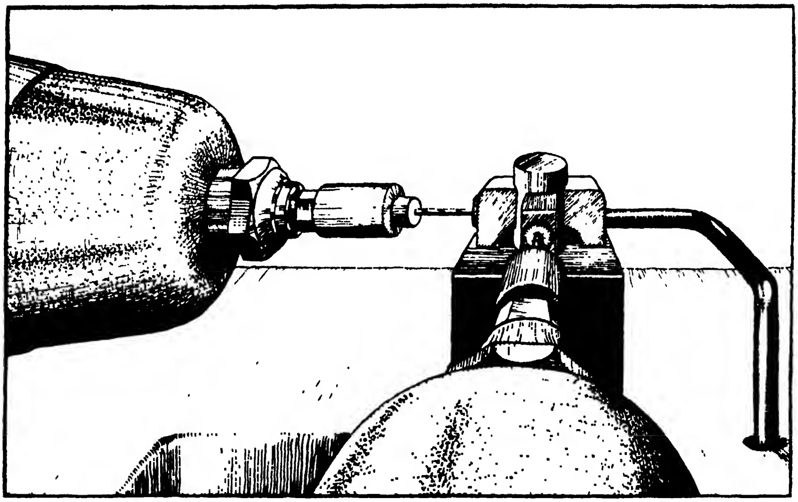


FIG. 6—*Drilling two holes simultaneously. The necessity for re-positioning the part and drilling the second hole separately can be avoided by using drills driven by portable grinders which are equipped with automatic feeding devices.*

MISCELLANEOUS OPPORTUNITIES.—The opportunities for increasing the effectiveness of manufacturing operations are limited only by the resourcefulness and staying powers of the analyst and the economic possibilities inherent in the situation. The analyst should, also, canvass the possibilities of (1) better planning in cutting and punching operations so as to reduce the wastage of material, (2) combining operations, (3) finding work for operators to perform to replace periods of enforced idleness, and (4) buying materials cut to size, prepacked in position for use, or perhaps already fabricated or processed.

The effectiveness of the operation can, of course, be improved if changes are made which serve to eliminate wasted

motions of the operator himself. The question of motion economy will, however, be deferred until after plant layout has been considered.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. The effectiveness of the operation, as it contributes to the whole process, is considered by the analyst. Name a few of the factors which might be examined with some expectation of increasing the effectiveness of an operation.

2. In the illustration given in the text did the designer intend that the hole and the slot be parallel? If not, why did he draw them that way?

3. What are some reasons for designers making "mistakes" in the sense that unnecessary difficulty is encountered by labor in performing the required operations?

4. Students of time and motion study often state that the design of the product and the materials specified should not be questioned by the observer or analyst. What is your opinion? Give reasons.

5. If the analyst notices that the operator is having difficulties with the material being used, what precautions should be taken by the analyst before a better material is recommended?

6. Can you think of an instance in which a change in an operation cut costs? Describe it.

PART III

PLANT LAYOUT

Chapter 7

MACHINERY AND EQUIPMENT

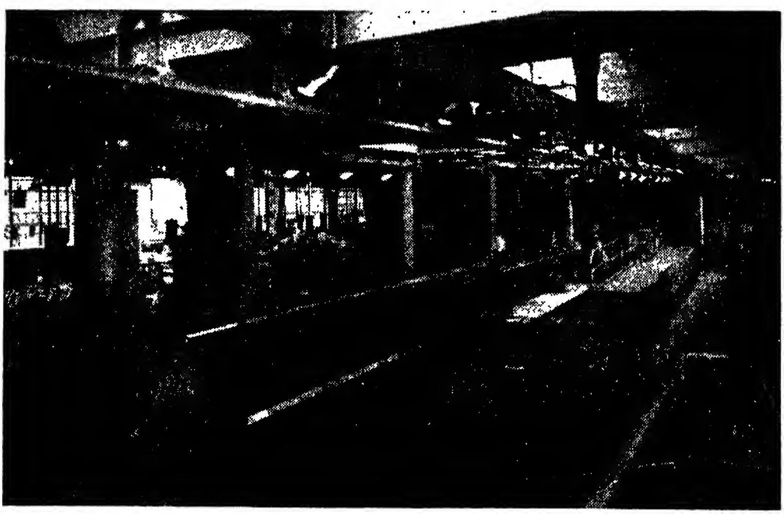
Although the primary interest of the analyst is not plant layout, he cannot ignore this important factor in industry. The difference between a good layout and a poor layout is the difference between a condition in which every move of materials counts and that in which materials are hauled around the plant unnecessarily. It is the difference between the full utilization of machinery and manpower and the enforcing of idleness and waste. Good layout helps to create profits; bad layout results in unnecessary loss.

THE NEED FOR LAYOUT CHANGES.—Just as a machine loses its usefulness if the product it processes changes too much or if a better machine is developed, so does a plant layout tend to become obsolete. Both must be kept up to date if they are to perform the functions for which they were designed. A machine may be scrapped and replaced if it becomes obsolete. A plant layout, on the other hand, seldom becomes outmoded all at once. Little by little, as the design of the product changes, as the materials used are changed, as new products are added and old ones dropped, and as variations in quantities produced occur, certain relatively minor changes in layout become desirable. Although these trifling alterations are inconsistent with the original arrangement they are tolerated because the entire plant cannot be "turned upside down" just because one machine is out of place. Such changes occur gradually, each too unimportant to merit attention, until eventually a condition results which approaches chaos. In this book we are interested in plant layout chiefly as it affects the efficiency of labor. If machines are arranged so as to require considerable walking on the part of the operator, frequent lifting of heavy materials, and the performing of

unnecessarily fatiguing work, the analyst looks for improvements which might be made.

The function of watching plant layout is entrusted, as a rule, to the master mechanic who consults with the foreman and the superintendent before important changes are made. In many of the larger concerns full-time attention is given layout by a specialized department. Many important factors of an engineering nature must be considered in laying out a plant and it is not surprising that often the human equation is ignored in the procedure.

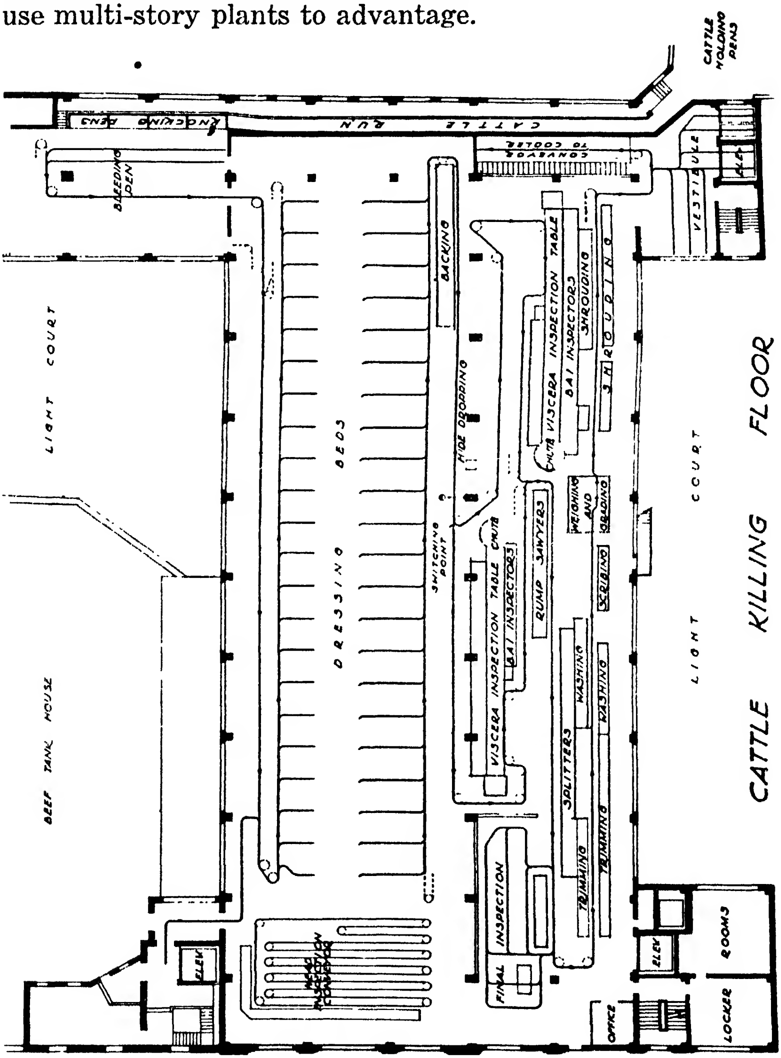
SPECIALIZED NATURE OF LAYOUT.—Layout initially must express the needs of the process. Meat packing, soap making, cement manufacturing, petroleum refining, flour milling, the manufacturing of automobiles and airplanes—all require special types of layouts. Some are analytic in nature, necessitating a branching out as the products emerge from the common raw material and progress through the plant. Others are synthetic in nature, calling for an entirely different type of layout, for in these one product is made from many raw materials. Often both forms are



Courtesy of Armour and Company

FIG. 7—*Photograph of a cattle killing floor.*

combined. Some industries, such as steel manufacturing, require single-story plants. Others, such as flour milling, use multi-story plants to advantage.



Courtesy of Armour and Company

FIG. 8—*A good example of direct-line layout; the cattle killing floor shown in Figure 7.*

Figure 7 is a photograph of part of the new cattle killing floor in the Armour and Company Chicago plant. Figure 8 is the layout of the floor. The photograph was taken from a point midway between the trimming and final inspection stations looking across the monel metal moving viscera inspection table toward the dressing beds. It was taken on the day the floor was opened and gives a better view than would be the case if all operations were in progress. Note the endless chain which moves continuously and from which the cattle are hung while being dressed. The viscera inspection tables move in synchronization with the overhead chain so that the carcass may readily be identified when diseased viscera are found. Note, also, the well-placed lights, conveniently located drinking fountains, and dry, raised platforms for the workmen to stand on. In Figure 7, note the direct-line, continuous, nature of the layout. Parts taken away from the main "dis-assembly" line drop down chutes and are processed in other departments on the floors below.

Direct-Line Layout.—It is generally conceded that a direct-line form of layout is desirable wherever it can be used. By direct line is meant a form which permits the material or materials to enter the plant at one end, progress through one process after another without backtracking or crossing the line of traffic, and which permits the finished product or products to emerge at the opposite end. This form of layout which is effective in both analytic and synthetic industries does not necessarily follow a geometrical straight line. Examples of direct-line layout are shown

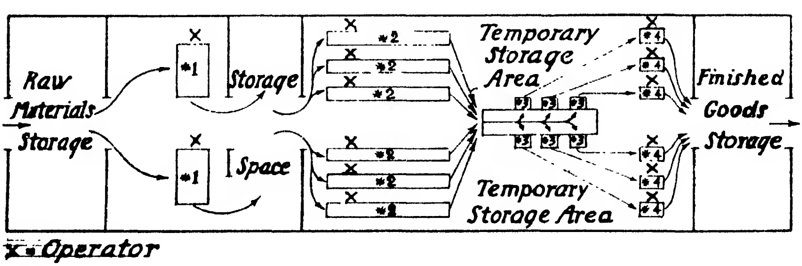


Fig. 9—*Layout illustrating the direct-line principle.*

in Figures 9 and 10. Often it is impossible to attain this ideal of direct-line production. If two or more products are manufactured in a given plant it may well be that the sequence of operations called for by the first product will not be the same as that called for by the second. Assuming that the plant is laid out in departments, consisting of groups of similar machines (as in Figure 9) it is readily seen that if direct-line conditions exist for one product it will be necessary for the second product to backtrack. The problem is further complicated if the second product requires an extra operation. If this second product is added after the first has been in production for some time, and if the first is being produced in greater quantity than the second, the average manufacturer would alter his layout as shown in Figure 11.

The route followed by the original product is shown by

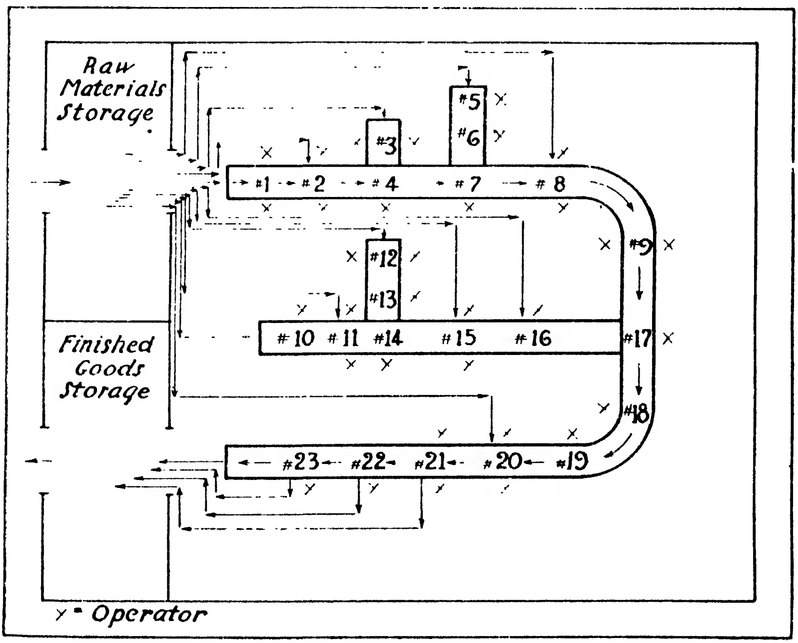


FIG. 10—*Direct-line layout does not have to be in a geometrical straight line.*

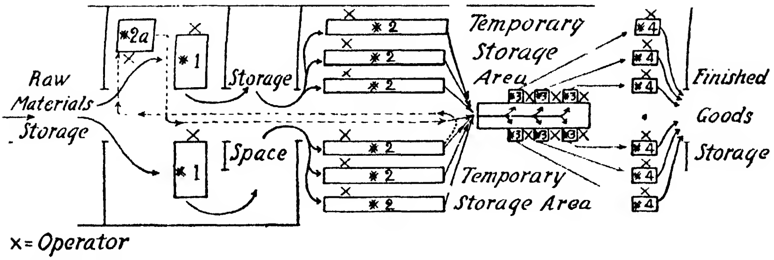


FIG. 11—*The effect the introduction of an extra process (2a) has on layout.*

solid lines, that of the new product by broken lines. Process 2a, the extra operation, is put in one corner of Department 1 because the space is available there. The logical place to put this extra operation would be somewhere between Department 2 and Department 3, but this would necessitate moving machinery and would result in too much crowding, so it seems to be easier at the time to transport materials than to move machinery, a necessary compromise with the ideal layout. If, however, the volume of the second product grows appreciably the progressive manufacturer would change from a layout that is built around groups of machines to one built around each product, as in Figure 12.

PROCESS VERSUS PRODUCT GROUPING.—In Figure 11, like machines are grouped together. This is known as process or functional grouping. In Figure 12, this arrangement has been broken up, the machines being arranged according to

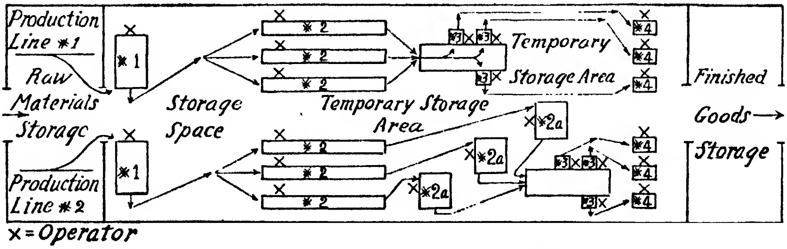


FIG. 12—*The first step away from machine grouping toward product grouping.*

the sequence of operations required by the particular product. This is known as product or line grouping. In the above example the original process grouping was broken up by introducing a second *product* which required the insertion of an extra operation. The original process grouping would be broken up, similarly (if the principle of direct-line production is to be observed), assuming that the plant manufactured only one product, *if a change in that product* made necessary a sequence of operations which called for the use of one type of machine more than once. Arranging the machines in the order of operations performed upon the product would serve to preserve the conditions requisite for a smooth, continuous flow of materials without the back-tracking that would have been necessary had the extra machines (called for by the new operation) not been so arranged.

Although the product-grouping form of layout is best for a concern that produces more than one article, as the number and variety produced increase, the process-grouping form tends to become more desirable. A system sometimes followed under such conditions involves laying out direct-line production units for a few products made in the greatest quantities and laying out the rest of the plant on a process-grouping basis for the remaining products.

THE ORIGINAL LAYOUT.—An original direct-line layout is made from the following data: (1) a manufacturing analysis of the product, which includes sequence of operations, tools and specifications, machines to be employed, and a description of the material to be used; (2) allowed time for each operation, if available, and if not, rated capacity of each machine; (3) floor space required by each machine; and (4) an estimate of the quantity of goods to be manufactured in a given time—important in determining the kinds, nature, and sizes of machinery and equipment to be purchased and installed and in determining their arrangement. As a working basis for determining scheduling requirements and the necessary number of each type of machine needed in the line, 80% of rated capacity generally is used if time standards are not available. Rated capacity may not be attainable in actual practice due to a variety of

reasons: it is based upon ideal conditions which rarely can be approached; it does not allow for breakdowns, necessary overhauling, and maintenance; nor can it take into consideration the failures, mistakes, and needs of the operator. Not only are these extraneous factors ignored in rated capacity of machine equipment but the question of actual time required by the operator to keep his machine operating usually is not considered by the vendor of the equipment. Occasionally, it is true, equipment manufacturers furnish standard time data for the various operations which their machines are designed to perform, but such data often are not fully utilized when the initial layout is made, for the layout engineers are interested chiefly in conforming to the needs of the product and getting the most effective use out of the plant and the equipment, and they are not so much interested in getting the most effective use from labor.

IMPROVING EXISTING LAYOUTS.—The analyst is interested chiefly in discovering possibilities of improving existing arrangements, and in systematically searching for such possibilities he is guided by certain principles. The layout should permit operators to secure, process, and dispose of material with a minimum expenditure of human energy. This implies the elimination or reduction of walking, bending, reaching, lifting, carrying, pushing, and pulling. At the same time, the layout should reduce idle time to a minimum. The analyst attempts to keep machines and labor reasonably occupied. First, he eliminates unnecessary operations and the unnecessary parts of necessary operations, then, when idle time results, he finds additional useful work for the machine and operator to do. The layouts which conform to motion-economy principles usually do not have an orderly, symmetrical appearance. If three successive operations, for instance, call for the use of a lathe, a milling machine, and a drill, and if the cutting operations on the first two machines are automatic, there may be no good reason why one operator cannot handle all three operations. To eliminate as much walking, lifting, carrying, trucking, and piling as possible the layout would be changed from the orderly appearing arrangement shown in Figure 13 to the less orderly but more efficient arrangement shown

in Figure 14. In the layout shown in Figure 13 it would be necessary for the operator to walk from machine to machine and to lift materials from the conveyor behind him.

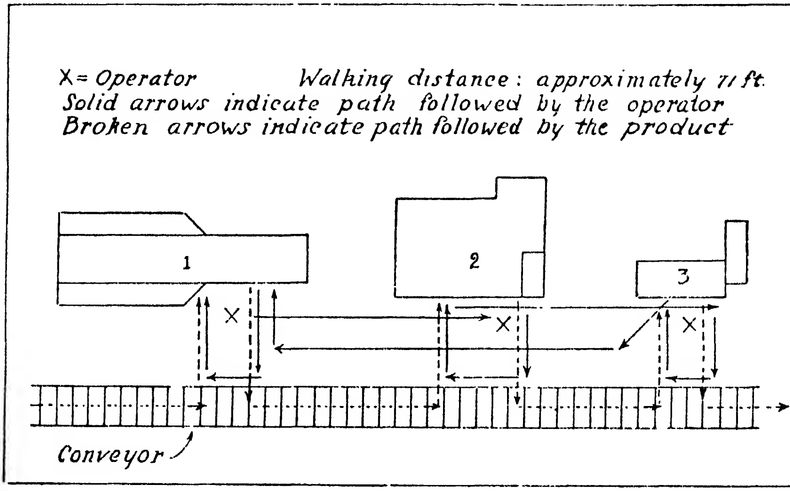


FIG. 13—*Arrangement of machinery in a straight line often makes it difficult for one operator to handle more than one machine, because of the necessity for excessive walking and materials handling.*

The arrangement shown in Figure 14 reduces the walking distance by approximately 48 per cent, and lessens material handling, with a consequent saving in time. Two questions usually are raised when it is proposed to arrange machines in this manner. One has to do with the possibility of spoiled work and damage to machinery while the operator's attention is diverted. To prevent such contingencies, an automatic shut-off device should be installed on each machine. The other question involves the matter of crowding. If it can be shown that a 50 per cent reduction in walking distance saves a given amount of money, why would not an arrangement which permitted a reduction of walking time almost to the vanishing point be still more effective? There seems, however, to be a point beyond which it does not pay to reduce the distance between machines. That point is

reached when the motions of the operator start to become cramped and restricted.

Machine grouping for labor utilization is not a speeding

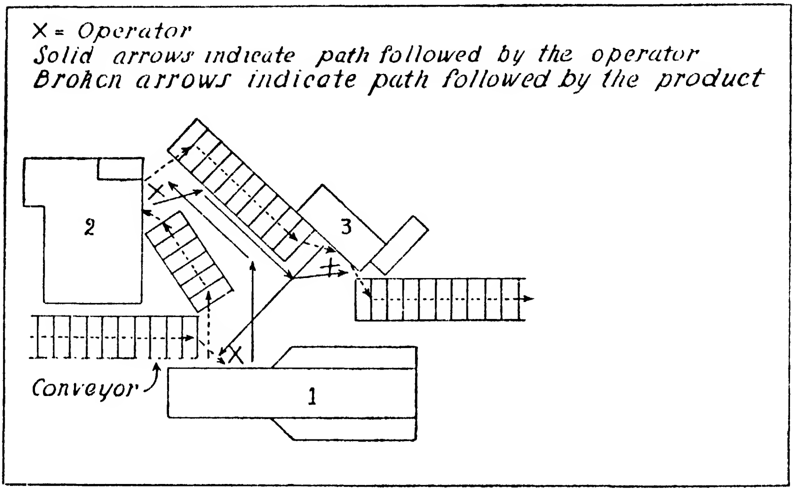


FIG. 14—*Machine grouping for labor utilization—more effective, although less orderly in appearance.*

up device as far as the individual worker is concerned—as a matter of fact, as has been mentioned previously, most workers dislike just to stand and watch a power cut or other automatic operation. They enjoy the activity and added responsibility involved in handling several machines at once. Objections are frequently raised, however, among certain types of operators, chiefly because custom has decreed that they should handle only one machine and spend most of their time idling. These individuals do not object so much to being kept busy; their objections are raised for the effect they will have upon their fellow workers who applaud these efforts to stand up for their "rights." The employer should, of course, not waste labor any more than materials, or cash, or his own time. To allow some workers to idle while others spend their time to better advantage is clearly unfair to the organization. In justice to the work-

er, however, his rate of pay should be, and usually is, adjusted upward as he takes on the responsibility of operating additional machines.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Why is it that the analyst cannot ignore plant layout?

2. What causes a plant layout to become obsolete?

3. "Layout initially must express the needs of the process." Explain.

4. What is meant by direct-line layout?

5. Describe the characteristics of product machine grouping and process machine grouping.

6. Why does process grouping become increasingly desirable as articles produced by a concern increase in number and variety?

7. The layouts which conform to motion-economy principles usually do not have an orderly, symmetrical appearance. Why not?

8. It is contended by a workman that machine coupling is a speeding-up device. What do you think?

9. What can be said in justification of the practice, often followed, of allowing machine-lathe operators to do nothing during an automatic operation, while an automatic punch-press tender is expected to keep busy?

Chapter 8

THE TRANSPORTATION OF MATERIALS

The layout of a plant is vitally affected by materials-handling methods. These methods must, of course, be determined before the original layout is made. The importance of choosing the correct methods can be appreciated when it is realized that in some cases as much as eighty per cent of the productive labor payroll is expended upon factory transportation. If the time spent by the operator in handling materials at the workplace[1] be included, this percentage becomes even greater. Materials handling at the workplace constitutes the very heart of motion study. Inasmuch as materials-handling methods between work stations affect the methods which must be employed at the workplace, the analyst's interest in this phase of plant layout can be readily understood.

THE ADVANTAGES OF GOOD MATERIALS HANDLING.—It has been pointed out[2] that good materials handling has certain effects. The efficiency of productive labor tends to be heightened; equipment and floor space are utilized more fully; the volume of goods being processed tends to be smaller; labor required merely to push materials from workplace to workplace is reduced; production control may be simplified; damage caused by handling may be reduced; and, last, good materials handling makes for more accurate scheduling.

KINDS OF EQUIPMENT.—Obviously the nature of the material handled is a basic determining factor when conveying equipment is selected: liquids, solids, large units, small units, powder, molten metals, acids, alkalies, fragile ar-

[1]Discussed in Chapter 13.

[2]In Anderson, Arthur G., M. J. Mandeville, and J. M. Anderson, *Industrial Management*, The Ronald Press Co., New York, p. 190.

ticles—all have their special problems requiring definite types of equipment for their transportation.

Materials-handling equipment may be classified in a variety of ways. A general classification would break these devices down into (1) those which transport vertically, (2) those which transport horizontally, and (3) those which transport both vertically and horizontally.[3] Equipment may be classified on the basis of products handled:

1. Equipment for handling bulk materials (sand, gravel, coal, etc.)

2. Equipment for handling individual units (boxes, barrels, bags, etc.)

Equipment may be classified on the basis of mobility: (a) portable, (b) self-propelled, and (c) stationary; and on the basis of the nature of the delivery: (a) continuous and (b) intermittent.[4]

The following detailed list of handling equipment for finished goods gives some indication of the range of choice open to the industrial engineer:[5]

1. Handling equipment for goods in bulk:
   (A) Flat-belt conveyors.
   (B) Troughed-belt conveyors.
   (C) Bucket elevators.
   (D) Screw conveyors.
   (E) Apron and pan conveyors.
   (F) Slat conveyors.
   (G) Scraper and flight conveyors.
   (H) Drag chain conveyors.
   (I) V-bucket and pivoted-bucket elevator conveyors.
   (J) Pneumatic conveyors.
   (K) Compressed air, steam, or water conveyors.
   (L) Drag scraper and drag line conveyors.
   (M) Skip hoists.
   (N) Car dumpers and special unloaders for ships.
   (O) Storage battery or gasoline-driven industrial trucks, tractors, and trailers.

[3] *Ibid.*, p. 191f.
[4] Alford, L. P., *Cost and Production Handbook*, The Ronald Press Co., New York, 1943, p. 854.
[5] *Ibid.*, p. 855.

(P) *Lift trucks—hand- or power-propelled.*
(Q) *Pumps.*
(R) Industrial railways.
(S) Ropeways and cableways.
(T) Cranes, hoists, and monorails.

2. Handling equipment for containers, platforms, skids, and pallets:
(A) Gravity roller conveyors.
(B) Spiral (helical) chutes.
(C) Straight slides.
(D) Apron conveyors.
(E) Slat conveyors.
(F) Live roller conveyors.
(G) Roller flight conveyors.
(H) Steel belt conveyors.
(I) Bar conveyors.
(J) Chain conveyors.
(K) Overhead trolley chain conveyors.
(L) Flat belt conveyors.
(M) Incline package or barrel elevators—bar, slat, and apron types.
(N) Vertical package elevators.
(O) Storage battery or gasoline motor-driven industrial trucks and tractors.
(P) Lift truck—hand- and power-propelled, direct and swivel.
(Q) Tiering machines—hand- and power-propelled, direct and swivel.
(R) Cranes, hoists, and monorails.
(S) Industrial railways.
(T) Motor trucks and trailers.
(U) Container cars.

In addition, innumerable special types of equipment might be listed, such as those which pack, wrap, and cut, as well as those which process (paint, dry, bake, plate, etc.).

Often it is tempting to suggest special equipment or complicated installations to solve a handling problem, but wherever possible the simple, commercial types should be used. They are cheaper from the standpoint of first cost as well

as that of maintenance. In case of a breakdown or an accident an alternative means of transport should be available.

CONDITIONS WHICH CAN BE IMPROVED BY THE USE OF BETTER EQUIPMENT.—The motion-study analyst often is able to cut handling costs by the use of materials-handling equipment. Before making recommendations for such equipment he looks for evidence of unnecessary handling, which usually is present if any of the following conditions exist: more than one man moving material without the use of mechanical equipment, men handling articles weighing in excess of 100 pounds, men loading or unloading trucks without the use of mechanical equipment, machine operators performing arduous lifting and carrying, workers moving materials from container to container, materials being moved from the unloading dock to inspection instead of being sent directly to the machine, any delay occasioned by lack of materials, retrograde movements of materials in process, and the use of antiquated methods or apparatus.[6] As a rule it is not economical to mechanize the moving of small, light parts. A common mistake made by analysts is that of attempting to over-mechanize operations. There is nothing wrong with letting high-priced operators walk a short distance for certain materials or small tools every hour or so during the day. It is true that anyone could do this work, but in the long run the relaxation which has been provided will result in better morale and greater productivity than would be the case if the expert machine operator or assembler were chained, as it were, to his workplace; for if all materials and tools are delivered to him he is certain to seek relaxation by extra trips to the drinking fountain and the wash room, with a consequent loss to the company.

ESTIMATING SAVINGS.—A common method of evaluating a proposed materials-handling installation is to compare the expected labor saving with the cost of the equipment. Often a rule is followed which serves to veto the purchase of such proposed equipment unless the expected labor saving during the first year is enough to pay for it. Such a rule, or any rule setting a fixed time in which savings must pay for

[6] *Cost and Production Handbook*, p. 852.

the equipment, is unreliable as a guide. In the first place, if only labor savings are considered, many possibilities for additional benefits accruing from the installation are being overlooked. In the second place, other expenses than the cost of the installation should be considered as an offset to the savings. And in the third place, the problem of evaluating the proposed equipment is not a simple matter of comparing the total of a few savings with the total of a few expenditures. Many factors must be taken into account if an estimate which is anywhere near accurate is to be made. Such factors would include the cost of installing the equipment (with the value of any lost production or shut-down costs included) ; interest on the additional investment; additional cost of insurance, taxes, and depreciation; increase or decrease in breakage; difference in maintenance charges; difference in cost of power, supplies, etc.; changes in accident hazards; difference in rent charged on floor space; increased earnings through increased production; and savings in direct labor, indirect labor, and overhead. These factors must be determined with care and applied with judgment. The analyst, in his report on any new method, determines as nearly as possible what effect the change will have upon costs and profits. The procedure he should follow is described in more detail in Chapter 22.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Why should materials-handling methods be determined before the layout is made?
2. How can the methods of handling materials between work stations affect the methods which must be employed at the workplace?
3. List as many effects as you can of good materials handling on industrial efficiency.
4. Name five different kinds of materials-handling equipment and tell what each is designed to move most effectively.
5. Give an example of a special type of handling equipment. To what extent is the motion-study analyst interested in such installations?
6. A slat conveyor, roller flight conveyor, spiral chute system is installed for the purpose of moving barrels from a filling machine on the second floor of one building to the first floor of the warehouse

across the street. What provisions should be made for possible breakdowns in the system?

7. Name five conditions which indicate to the analyst that materials-handling costs are too high and probably can be reduced by the use of handling equipment.

8. How can better handling methods reduce delays occasioned by shortages of materials in the fabricating departments?

9. Why is it often poor practice to mechanize the delivery of small parts to the workplace?

Chapter 9

WORKING CONDITIONS

Those environmental features of a place of employment which are commonly known as working conditions frequently have a profound influence upon workers. In order to get the most from human energy it is evident that as many as possible of the conditions which surround labor should be those which are the most favorable and the most conducive to clear thinking and constructive activity.

ILLUMINATION.—Over thirty years ago Frank B. Gilbreth stated[1] that if one examined every light in any factory he would, as a rule, find them obviously wrong in that they would fail to pass one or more of five tests: they would be insufficient in quantity for satisfactorily seeing the work, they would be so placed as to cause the user's eyes each to change the size of the diaphragm, they would not be steady, they would reflect from bright spots into the eyes of the workman, or they would shine into the eyes of other workmen.

Although illumination engineers have made great progress since Gilbreth's observation was recorded, nevertheless, there is still need in the average plant for someone to give attention to frequent violations of the rules of good illumination. This is one of the duties of the motion-study analyst.

The term "illumination" refers to the quantity of light which is reflected from objects. Illumination is measured in units of lumens. A lumen is the amount of light which is required to illuminate an area of one square foot to an intensity of one foot-candle. A foot-candle is the intensity of illumination at a point one foot distant from, and per-

[1] *Motion Study*, D. Van Nostrand Company, New York, 1911, p. 51.

pendicular to, the rays of a one candlepower light source. The candlepower is the unit of luminous intensity, and is the average intensity recorded horizontally from a "standard" candle—one made and burned in a given manner.[2] The term "lighting" refers to sources of illumination.

There are many arguments to support a policy favoring adequate and correct illumination. Many of these are of secondary interest to the analyst, but they can be used to support his efforts to correct a bad lighting situation if such arguments are needed. There is ample proof on record that insufficient lighting contributes to an unnecessarily high accident rate. Dark workplaces are, also, bad on employee morale. Even though the workplace is well lighted, if the entrance, hallways, and stairways leading into the plant are dark, employees dislike entering. Adequate lighting encourages cleanliness, discourages loafing in dark corners, results in less eyestrain, and decreases the expenditure of nervous energy, all of which have adverse effects upon production. But varying degrees of illumination have more direct effects upon performance than these. Logically, it seems that adequate lighting would tend to give workers a deft assurance at their tasks which they would not otherwise possess, and that the net result would spell less spoilage and greater achievement. An aim of motion study is to reduce uncertainty, hesitation, and needless motion, all of which result from insufficient illumination of the workplace. Starting from a condition of insufficient illumination, it is true that increased illumination should result in increased production. But the analyst should not assume that under all conditions of lighting an increase in candlepower is beneficial. Often a *decrease* in candlepower results in more production per operator, a result which can be explained, perhaps, by one or more of the following conditions: (1) originally there was too much light and the reduction resulted in more favorable illumination, (2) the reduction served to eliminate or reduce glare, (3) the

[2]*Artificial Light and its Application*, Westinghouse Lamp Company, p. 40. Cf. Anderson, Mandeville, and Anderson, *Industrial Management*, 1942, p. 239 f.

reduction was not great enough to result in unfavorable conditions and the realization by the employees that something was being done to benefit them caused a reaction which increased productivity, and (4) a change of any kind often causes employees to work better and the change in lighting (if within proper limits) probably was no exception.

Deep shadows should be softened, not eliminated. Better distribution of light can be accomplished by the use of many light sources placed high in the room. If more light is needed at the workplace, additional local sources, well shaded and correctly directed, can be provided. The analyst should look particularly for evidence of glare. Glare often results even under conditions of insufficient illumination, and frequently it is difficult to eliminate. Whether caused directly or by reflection it is a potent cause of eye fatigue, vision impairment, and discomfort. Glare is caused (1) by a too brilliant light source, (2) by a light source located too close to the eyes, (3) by too great a volume of light (as from a window), (4) by long exposure to a light source, and (5) by too much contrast between the light source and the background. When the eyes strike a spot which glares, the diaphragms close in about one second. A delay of one minute is required, however, for them to re-adjust to normal light again.

One of the requisites of good illumination is that the light should be of the right color. For ordinary work white light is best. Mazda lamps reduce the red rays which are emitted by incandescent lamps and produce an approximation to afternoon sunlight. It is desirable to reduce the volume of red rays, for red rays irritate the eyes. Mercury vapor lamps permit discernment of fine detail and they are often used where such work is performed. Workers (especially women) object to this type of light because of its unnatural color. This objection can be removed by the use of a few incandescent lamps, or other types of illumination which add a small quantity of red rays. Other objections are occasionally voiced by those whose eyes and skin are peculiarly sensitive to this type of light; such people complain that it causes headaches and a slight skin irri-

tation or rash. The mercury vapor light is composed of 90 per cent yellow and green and 10 per cent blue and violet. The most efficient lamps are the Cooper-Hewitt fluorescent type which produce about 50 lumens per watt, while incandescent lamps produce only from 15 to 20 lumens per watt.

An important factor in illumination is the finish and color of the walls, ceilings, machinery, and equipment. A stippled finish is better than a smooth finish for walls and ceilings. The upper parts of rooms should be painted in lighter colors than the lower parts. Machinery and equipment should be painted grey or drab rather than black.

Walls, reflectors, fixtures, lamps, windows, etc., should be cleaned regularly, as intensities of illumination drop considerably if this is not done. The analyst should look, also, for any signs of flicker at the workplace. Such interruptions of light frequently are caused by boxes passing along a conveyor between the light source and the workplace. Shafting, wheels, and belting, by being similarly placed between the light source and the workplace, also cause flicker.

It was the opinion of Frank B. Gilbreth that light in a factory is the cheapest thing there is.[3] As a matter of fact it is rare that light costs over one cent per hour per worker. Nevertheless, there are misinformed supervisors who spend much of their time turning out lights to save money, but in doing so they may actually add expense by wearing out lamps and switches, by causing increased accident rates, and by encouraging in the employees a feeling of repugnance toward their place of employment. Gilbreth pointed out that the difference between the cost of the best lighting and the poorest was nothing compared with the saving due to decreased time required to rest fatigued eyes. This is borne out by an estimate made by the automobile industry[4] in which it was indicated that by lowering lighting costs 10 per cent, the cost per car would be reduced one cent but by *raising* lighting costs 10 per cent, the saving per

[3]*Motion Study*, p. 51.

[4]Anderson, Mandeville, and Anderson, *Industrial Management*, 1942, p. 254.

car would be 25 cents. It is false economy to attempt to cut costs at the expense of good illumination.

NOISE AND VIBRATION.—Considerable experimental evidence is at hand which bears out the contention that noise affects the human organism adversely. It is, however, difficult to translate this evidence into terms of production rates. It is estimated,[5] "though this figure cannot be verified," *that the total output* of an office is reduced about ten per cent when conditions change from reasonably quiet to noisy. Efforts have been made to decrease noise in offices by using noise-absorbing materials for ceiling, wall, and floor coverings, and by placing felt pads under typewriters and other office machines. High-pitched, metallic sounds have been reduced by these means, but low-pitched sounds are not affected. Less effort has been expended in reducing noise in factories, though occasionally we find that especially noisy operations have been segregated in soundproofed rooms. It is often said that the human mechanism gets used to noise, and often a background of noise causes slight production increases. What actually happens is that more energy is required to overcome the effects of noise so as to produce the same quantity of work, and in attempting to overcome the disturbing effects of noise the human mechanism is stimulated. While it may not cause a diminution in automatic performance, noise often does tire the worker unnecessarily. Old-fashioned professors of mathematics, Latin, and Greek often extol the virtues of their fields on the basis of the mental discipline such studies provide for the student. The writer once had such a teacher who attributed his superior mental powers to the fact that he had been forced to study in his father's store with all of the distractions such an environment affords. Collegians often even attempt to study while listening to the radio! Whatever may be said in favor of developing the mind by forcing it to concentrate, little can be said in extenuation of such a practice if mental accomplishment in terms of quantity and quality of work is desired. Loud noise, intermittent moderate noise, novel, strange, or un-

[5]Donald, W. J., *Handbook of Business Administration*, McGraw-Hill Book Company, Inc., New York, 1931, p. 763.

usual sounds, all have a disturbing effect upon one who must give close attention to his work, and we should regard as an absurdity the attitude that workers should rise above their surroundings and not "allow" noise (and other unfavorable conditions) to disturb them. Managers should remove as many as possible of such obstacles to production.

Vibration should be eliminated wherever it is found. A vibrating machine is an inefficient machine and there is evidence indicating that the effects of vibration upon the human frame are even more deleterious than noise.

Air Conditioning.—Perhaps the greatest need for air conditioning exists in plants in which the manufacturing processes quickly vitiate the air; fill it with fumes, dust, or odors; or cause exceptionally high temperatures. State factory inspectors, as a rule, are able to control the worst cases, but most state factory laws still allow conditions to exist which the progressive manufacturing concern would not tolerate. There is, therefore, plenty of scope for the improvement of conditions in the average plant. Such improvements usually must be suggested by the analyst, for workers often do not complain unless conditions are intolerable, and even then they prefer to quit and look for another job, rather than complain. Perhaps they have learned that complaining does no good, so they accept the bad conditions as part of the job, and the employer loses the output he might have got had the plant surroundings been more favorable. Industrial engineers have frequently noted production increases of ten per cent, sometimes even more, simply by an improvement in the air supply. When such conditions as drafts, wet floors, noxious fumes, dust, excessive heat, etc., exist, the possibilities of increasing individual performance are even greater.

Frequently the requirements of the process dictate the conditions which must exist, and often such conditions are disagreeable or even injurious to the health of the employees. In many cases little can be done, for the process comes first. But often much could be done if a little attention were given to the problem. Unfortunately, the ill effects upon the workers are not immediately evident in

many cases and, strange to say, really dangerous conditions are tolerated by employees more often than are harmless but disagreeable conditions. For example, there is a real danger in breathing air which contains particles of silica, volcanic ash, and other types of mineral and rock dust. Nevertheless, it is often practically impossible to enforce rigid company rules requiring the wearing of respirators. The answer of one worker to such a rule was: "It takes a real man to work here—and *I* can *take* it." Three months later he died of what the doctor called pneumonia. It is not hard to find people who will work under such dangerous conditions, yet vociferous remonstrances are made over harmless, but disagreeable, odors.

A mistake which frequently is made is to overheat factories. Proper temperatures and an adequate supply of fresh air can be provided at a comparatively low cost and, at slightly more expense, the proper degree of humidity can be maintained. It has been determined[6] that the worker is most comfortable at 70 degrees with 50 per cent relative humidity. Approximately constant results may be maintained by changing two or more of three factors: (1) temperature, (2) humidity, and (3) air movement. It is possible to obtain cooling effects by lowering the temperature, by reducing the moisture content of the air so as to increase its evaporative effect, or by circulating the air.

SAFETY.—Occasionally the motion-study analyst may devise a method, or the time-study observer may establish a speed rate, which will be declared to be unsafe by the safety engineer, but as a rule there is no conflict between efficiency and safety. From the standpoint of the person who wishes to increase the effectiveness of industrial personnel, safety is doubly desirable: its humanitarian aspects result in higher morale (with all that this implies in the way of increased productivity), greater employee cooperation, the attractiveness which the plant has for higher type workmen, and its economic aspects result in lower costs through less lost time, lower labor turn-over, and

[6]At the University of Illinois. See Anderson, Mandeville, and Anderson, *Industrial Management*, 1942, p. 268.

the decreased restraint and nervous tension which results from the fear of being injured.

The safety program of a plant is usually under the direction of either a safety engineer or a director of safety, and may be placed, in the tables of organization, under either the plant engineer or the personnel manager. Accident prevention involves considerable work of a psychological and promotional, as well as of an engineering, nature. The heads of the standards and safety departments should work in harmony, for each is interested in getting the greatest amount of productivity from a given expenditure of human energy and each is interested in the welfare of the employees. Unfortunately, however, it is customary to express accident statistics in terms of "hours of lost time per million hours worked" in a given plant or department rather than "hours of lost time per million units produced." Hence, in his zeal to make as good a showing as possible, the safety engineer may design guards and controls guaranteed to prevent accidents, but resulting, at the same time, in decreased performance and increased fatigue. The best interests of both the employer and the employees are served when plant conditions are checked and approved by both departments.

Often the head of the standards department sits on boards of inquiry investigating the ultimate causes of accidents in the plant. Occasionally the claim is made by someone that an accident was caused by the haste of the operator to cut corners so as to earn more bonus money under the incentive system. If such is found to be true, preventive measures should include increased attention to safety devices and safety education, not abolition of the incentive system, as someone is sure to suggest.

MONOTONY AND MORALE.—Efficiency is not necessarily promoted by keeping workers persistently on the job. They require brief periods of relaxation and they greatly appreciate the opportunity to leave the workplace occasionally. Clean, sanitary locker rooms and rest rooms, plenty of cool drinking water from conveniently placed fountains, cold-drink and candy dispensers, and coffee and lunch counters, are a few of the conveniences now considered by manage-

ment to be a necessary part of the well-equipped plant. The question may well be asked, however: "What is the sense of cutting a fraction of a minute from a work cycle and timing a job to the nearest hundredth of a minute, when the workers kill time in a locker room, at the coffee counter, or around the 'coke' dispenser?" The answer is that two entirely different things are involved. Timing is done to compare alternative methods, to aid in improving methods, and to establish standards. A reasonable allowance for personal needs and relaxation is added to each standard. If a worker wants to "loaf" over a cup of coffee during business hours, that should be no concern of the supervisor, provided, of course, the worker left his workplace legitimately. Split-second precision in setting time standards does not imply unvarying, split-second performance on the part of the operator. Far from it.

Division of labor has been accused of introducing monotony into the lives of workers, and motion study, by encouraging division of labor, has come in for its share of criticism. Monotony may be personal or environmental in its inception. A job, which may be interesting to each member of a group performing it, may be divided and subdivided until in its "re-engineered" state it may become monotonous to all. Or, with no apparent change in the job, a worker may "go stale." The latter is the sort of case to which those may point who contend that monotony is personal or individual in nature. The fact that only one person considers the job monotonous and all of the others doing the same work consider it interesting, tends to prove, such people believe, that it is the worker and not the work itself which causes the unfavorable reaction. As a matter of fact, there are a number of factors involved in this matter of monotony. In the first place, it existed long before the introduction of division of labor. As a causal factor, division of labor can be blamed for only part of it. A farmer's work is more or less monotonous, depending upon whether he is constitutionally and inherently adapted to the work; whether he owns his place or works for another; whether or not he is getting ahead financially; whether he enjoys a pleasant home life; whether he obtains relaxa-

tion, change, and recreation; etc. These personal factors all apply as well to an individual who works in a manufacturing plant. There is a second set of factors which is environmental in nature. The same farmer who found life satisfying and interesting in wooded and hilly Eastern Kansas or among the lakes of Minnesota might find the monotony unendurable on the plains of Western Kansas or in Central North Dakota. Likewise, the interior of a factory can be drab and uninteresting, or it can be fascinating. The writer has been told by Western Kansas pioneers that homesteading in that inhospitable land was interesting and anything but monotonous because every half mile or so lived a young, congenial couple. The factory worker who likes his associates and who is treated well by his supervisor usually does not go stale. So the question of monotony is seen to be exceedingly complex. It can occur more easily for some persons than for others; it may occur more easily where conditions are bad; it can be prevented often by allowing workers to visit and converse while working; music often keeps it away; bad treatment by the foreman encourages it; a job which contains too few elements or operations, also, encourages it; opportunity to leave the workplace occasionally, or a measure of personal freedom, tends to keep it away; a genuine opportunity to gain experience, promotion, and increased pay, no matter how bad the conditions may be, often keeps one's morale very high and enables one to overlook any tendency the immediate job may have toward monotony, but hope too long deferred often causes a sudden violent revulsion; regular vacations are a necessity, and one day of rest in seven helps to provide the variety which keeps up enthusiasm; a vision of the vital necessity of the job (as in the case of war work) often helps; and last, on a list which does not by any means exhaust the influences which tend to cause or prevent monotony, is the home life of the worker, which, if it is normal, tends to heighten morale, but which may, through death, quarreling, dissipation, or lack of understanding and sympathy, empty the job of much of its meaning. Any program of economy in industry should provide for an investigation (possibly by the standards department) of the

causes of monotony and the removal or mitigation of such causes through the use of incentive systems, decent treatment, good conditions, and all of the other devices and practices employed by enlightened management; and the standards department should not help to create monotonous conditions by laying out uninteresting workplaces, by removing variety from the jobs of the workers, or by discouraging all personal freedom during the work day.

MUSIC IN INDUSTRY.—Interest in the use of music in industry is increasing. There is no doubt that music can improve morale, but can it help to increase production or does it interfere with the productivity of the workers? According to three controlled experiments made at the Twin Cities Ordnance Plant, Minneapolis, the use of music had the following effects:

1. After using music, production increased 19.76%.
2. After stopping the use of music for one week, production decreased 18.53%.
3. 101 days after music had begun being used, AWOL absences decreased 34.1%.[7]

In a speech before the Twin Cities Society of Industrial Engineers at the University of Minnesota, Mr. R. W. Roddy, of the Twin Cities Ordnance Plant, made the following suggestions concerning the use of music in industry:

1. Variety is essential to proper stimulation.
2. Play "peppy" music for five minutes prior to and ten minutes after starting time.
3. Play "lift" music for twenty minutes before the first let down period, one-quarter of the way through the shift.
4. Play "dinner" music (waltzes, Victor Herbert, light opera) during the forty-minute lunch period.
5. Three-quarters of the way through the shift play "lift" music for twenty minutes.
6. One hour before the end of the shift play more "lift" music for twenty minutes.
7. Finish the shift as it started, with "peppy" music.

This procedure, it should be observed, does not work the employee harder during the day, but more evenly. As for

[7] Murray, Robert, L., *Special Bulletin No. 1*, "Music in Industry," American Society of Composers, Authors, and Publishers, New York.

the selections, let the production figures, not the employees' requests, be the judge of what is best to play.[8]

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What is a lumen? A foot-candle? Candlepower? Illumination? Lighting?
2. "Increased illumination results in increased production." Is this statement true? Discuss.
3. Why should deep shadows be softened? Why should they not be eliminated entirely?
4. Describe a system of lighting which will provide adequate illumination at workplaces where fine, exacting assembling is done.
5. What causes glare and why is the analyst interested in eliminating it?
6. Of what value is color in artificial lighting?
7. How should walls, ceilings, floors, machinery, and equipment be finished and painted in order best to aid perception?
8. What effect might noise have upon the productivity of a workman?
9. Is it possible for a person to "put noise out of his mind" and not feel its effects?
10. Why does the analyst not leave such matters as the eradication of fumes, dust, etc., to the state factory inspector?
11. Can you explain workers' antipathy to disagreeable but harmless odors and their lack of aversion toward silicosis-causing dust?
12. The air can be made to feel cooler without lowering the actual temperature. By what two ways can this be done?
13. Time- and motion-study analysts favor safety programs because of their humane and economic aspects. Explain.
14. Give examples of the psychological, promotional, and engineering features of safety work.
15. Give an example of a machine control designed to protect the worker's hands but which serves to decrease efficiency. Do you think it possible in this example to change the design so as to retain safety and at the same time promote efficiency?
16. Reconcile the paradoxical situation in which work cycles are timed and standardized to the hundredth part of a minute while workers are allowed to visit around the drinking fountain.
17. How do you account for the fact that some people get used to monotonous jobs and actually enjoy working at them while other people start on jobs which at first are interesting but which later become monotonous to them?
18. Is monotony an individual matter or is it caused by external factors in the environment?
19. How can the motion-study analyst help to combat monotony?

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[8] *Ibid.* See, also, a series of booklets entitled *Music in Industry*, by R. L. Cardinell, published by the ASCAP.

Chapter 10

LAYOUT TECHNIQUES

The problem of making a plant layout is one which involves arranging and rearranging machines and equipment so as the meet (1) the demands of available space, (2) the requirements of the processes involved, (3) the requirements of the personnel, and (4) the policy respecting methods of handling materials. The layout must reflect a reasonable compromise (1) between space that could be used conveniently and the cost of space, (2) between the space occupied by materials and that used by the machine and by the operator, (3) between the cost of moving machines and the advantages of maintaining flexibility, (4) between the needs of the layout and the desire to provide an orderly appearing plant, (5) between the "ideal" arrangement and that forced by obstructions, by the need for accessibility to machines, or by the need to maintain visibility for proper supervision, (6) between straight-line layout and special conditions which often make it more advantageous to take a process out of its logical place and put it elsewhere in the plant, and (7) between the advantages of the theoretically correct layout and the disadvantages of purchasing special machines. There are so many such compromises or exceptions in the average layout problem that it has been found necessary to develop special techniques in order to save time in arriving at acceptable solutions.

FLOW DIAGRAMS.—The first step toward making an improved plant layout is to secure or draw scale floor plans of the plant showing the present layout. Strictly speaking, a plant layout shows only the locations of machines, equipment, storage space, aisles, etc., within the plant setting. The routes followed by the various products as they are moved from work station to work station are not shown.

Flow diagrams, made either by sketching in these paths on the layout or by putting them on tracing paper placed over the layout, are extremely useful in preparing to improve existing arrangements. The tracing paper technique is especially useful when a large variety of materials and products is handled, as a different sheet of tracing paper can be used for each material, part, or product, thus reducing the confusion that results from showing all paths on the same plan. Ordinarily, however, if there are not too many principal parts or materials, their paths may be drawn on one layout sheet. When this is done, their varying importance should be shown by lines of different width. An "important" product is one that possesses weight or bulk, or is one that is handled in greater quantities than the others. The new layout will, of course, be made so as to shorten the paths of the products most difficult to handle. In a soap plant, for instance, the crutchers should be so placed as to facilitate the handling of the filling materials which are more difficult to handle than is the hot kettle soap, which can be piped to any point in the plant. Likewise, in the manufacture of chip soap, the chips can be blown or otherwise conveyed to distant points within the plant more easily than barrels and boxes can be moved. Consequently, the layout should attempt; primarily, to shorten the paths followed by packed containers. An example of a flow diagram is shown in Figure 15. Note particularly (1) processes out of place requiring long hauls and backtracking, and (2) crossing traffic, often a potent cause of delay.

By showing the paths of the products which are the most difficult to handle in such a way that they will stand out on the flow diagram, the analyst makes it easier to start improving the layout. The light lines may be lengthened, if necessary, but the new arrangement must result in shorter paths and less handling for the materials represented by the heavy lines. It is useful, also, to mark with a heavy circle each point where traffic crosses. Then, last, all fixed features in the existing layout should be outlined heavily so as to make them stand out clearly. Such features would include walls or partitions which cannot be removed, elevator

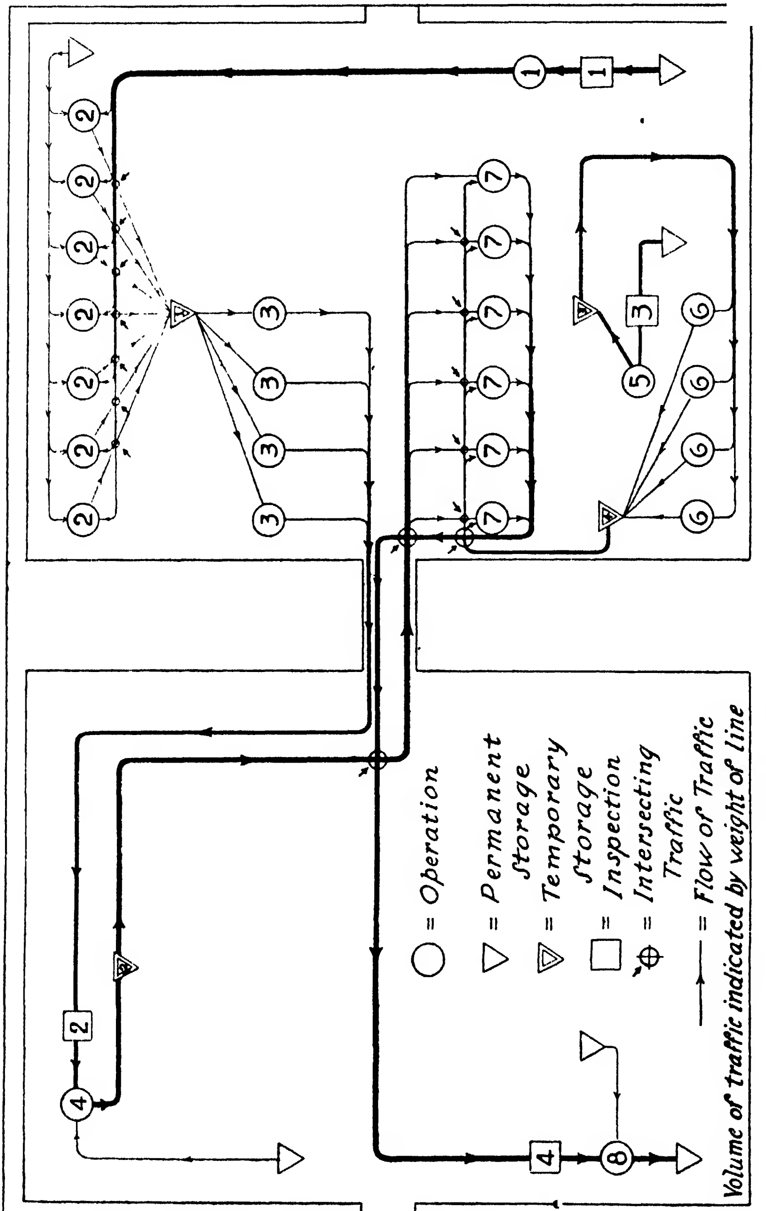


Fig. 15—Flow diagram of a poorly laid out plant

shafts, locker and wash rooms, stairways, windows, columns, overhead obstructions (these should be clearly marked as such with the clearance in feet noted), and heavy machines or installations which could not be moved except at prohibitive cost. In case heavy machines are to be moved it is useful to have variations in floor strength indicated, too.

The chief value of a flow diagram is its aid in visualizing the important aspects of a layout problem. It is possible, of course, to see evidences of bad layout by inspecting the plant itself. Traffic jams, excessive handling of materials, etc., can be noted—but the reasons for them cannot easily be visualized. It is difficult to keep in mind all of the factors which should be considered, and should a change be made without the aid of a flow diagram it is possible that one set of bad conditions would be substituted for another, for, as difficult as it is to visualize the existing layout, it is practically impossible to visualize, at the same time, the multiplicity of detail involved in making layout changes.

CHARTS.—Three types of charts are found to be of help at this point: the operation chart, the flow chart, and the machine-and-operator time chart. The operation chart (shown in Figure 16) is useful in suggesting the ideal layout (which, of course, has to be altered to conform with the requirements of the building and of the fixed points). Briefly described, the operation chart shows the sequence of operations for a relatively simple process. For highly complicated processes, such as those in airplane or automobile manufacturing, the various sub-assemblies or individual processes are charted separately. Horizontal lines represent the entry or departure of materials, parts, or sub-assemblies into or out of the process. Vertical lines indicate the succession of operations, which are shown in the proper order along the line in the form of circles for manufacturing operations and squares for inspecting operations. These operations are equally spaced along the vertical lines—no significance is attached to the distance between successive operations. Usually numbers placed in the circles and squares indicate the order (but not necessarily in point of time) in which the operations and inspections occur. Often the operations and inspections are numbered in sepa-

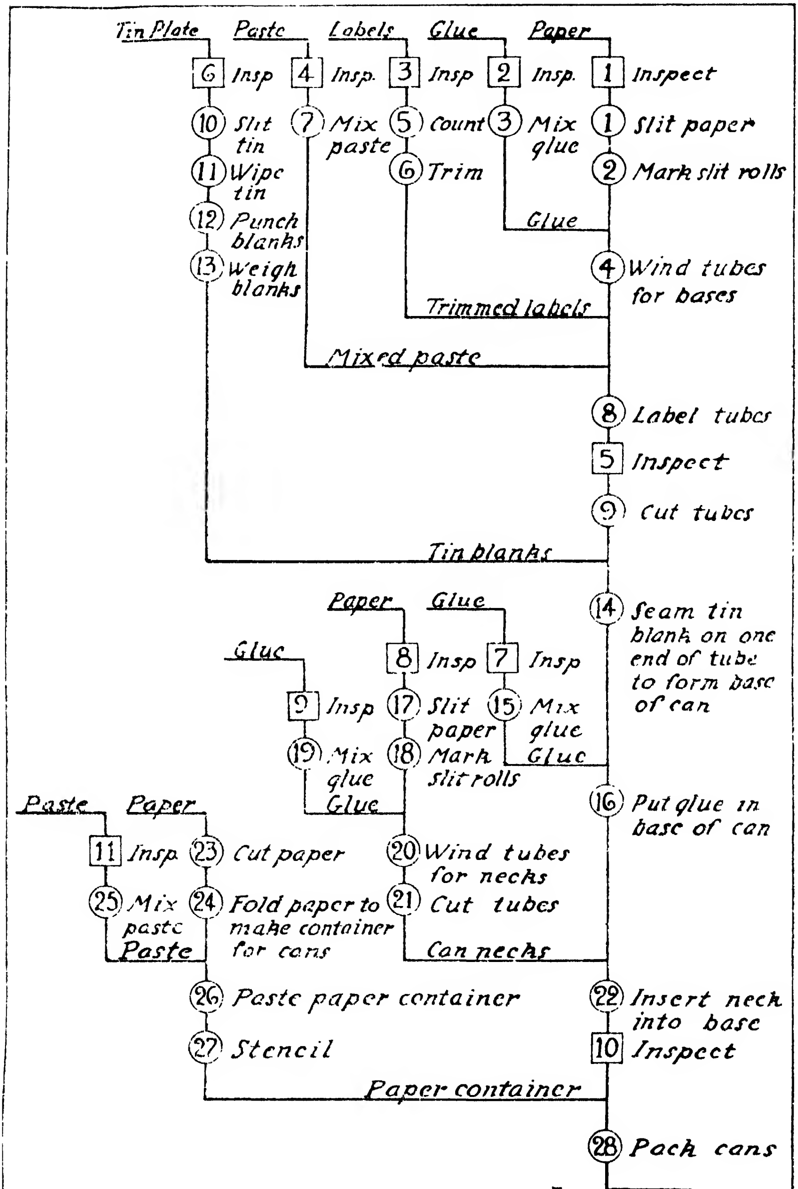


FIG. 16—*Operation chart for a synthetic process.*

rate series. At the left of each operation and inspection may be shown the standard times required, while to the right the operations are described. Each horizontal line is labeled with the name of the material or product it represents and each group of processes is labeled with the name of the product or sub-assembly represented. Distances traveled, points at which materials are stored, and the time materials remain in storage are facts which do not appear on the operation chart. Industries in which the products made are few in number and those in which the products are altered only slightly from year to year are the easiest to chart. On the other hand, if there are many products and if the products change often, the industry is difficult to chart. Although such charts are easier to make for stable industries, there is less need for them, for layout problems are not so pressing. But in the case of a concern doing a jobbing business, the charts are harder to make and the need for them is great, for the difficulties of keeping up with changes often keeps such a plant in a chaotic condition. Generally, in such concerns, the layout of the plant is frequently changed so as to conform to the requirements of the principal products.

The flow chart (Figure 17) indicates the following data: the succession of operations, inspections, temporary and permanent storages, and each transport; the time required for each storage, transport, and operation; and the distance of each move. Again, distances on the chart have no significance. The flow chart is of particular advantage in clearly showing such information as time spent in temporary storage and distance traveled by the material, both of which, when unnecessarily great, tend to add to the cost of the product by slowing delivery dates, requiring greater investments in goods in process, requiring more storage space, and consuming energy in moving the product from workplace to workplace. The flow chart should be constructed from information secured at first hand in the plant. Even those who are most familiar with the plant, when they attempt to compile the information for flow charts, often estimate times and distances erroneously, and may frequently omit vital information. Several other forms

Material or Part *Labels for 15/16" tubes*

△ Outside Operation	▽P Permanent Storage	▽T Temporary Storage	□ Inspection	○ Transportation	◯ Inside Operation	Feet	Minutes	Description
								Label paper rec'd dock c
						50	.80	Move to checking station
			1				1.00	Check paper
						250	3.50	Push truckload to elevator #3
							.15	Ring for elevator
							1.00	Wait for elevator
							.30	Push truckload into elevator
							.25	Ascend one floor
						250	3.50	Push truckload to storeroom
					1		2.00	Unload and pile bundles
							2400.00	Storeroom. Avg. time 5 days
					2		2.00	Load truck
						500	6.00	to paper cutter
							240.00	Wait for operator
					3		65.00	Cut and trim stock
					4		3.50	Place 15/16" labels on truck
							960.00	Wait. Avg. 2 days
						150	2.00	Push truckload to label room
							60.00	Wait for Operator
						30	.70	Push truckload to pasting machine
					5		300.00	Feed labels into machine
						50	300.00	on conveyors to labelers
					6		300.00	Hand label tubes
						1280	4651.70	Totals

FIG. 17—*Flow chart.*

of flow charts are in common use, but the form shown in Figure 17, is believed by the writer to be the easiest to prepare, and to be as clear to comprehend as any of the others.

The machine-and-operator time chart (Figure 18) is of help in arranging machines so that more than one may be handled by an operator. Operators who tend automatic or semi-automatic machines often have a substantial portion of each work cycle available for useful work. The machine-and-operator time chart is simply a time study of a machine operator charted with actual machine time shown separately but at the proper place in relation to the complete work cycle of the operator. It helps the man who makes the layout to visualize the relationship between working time and waiting time in each work cycle. Thus, if the waiting time of an operator working on one machine is seen to be more than three times that of the working time, it seems evident that the operator could handle at least two more machines—possibly three. Due precautions will, of course, have to be taken to prevent possible increases in material spoilage when one operator handles more than one machine.

Often the advocate of machine grouping for labor utilization must overcome considerable opposition to his ideas. The machine-and-operator time chart is useful, too, in this connection, for when time quantities are measured out along a line they attract attention and carry conviction as figures alone can never do.

Supplementary Information.—Additional data needed by the layout man will include knowledge of long-range plans for expansion; estimated sales or quantities to be produced during the coming year; policies with respect to the number of hours to be worked per day and per week, number of shifts to be operated, working days in the year, etc.; special requirements of the process and the effect upon needed equipment, as, for example, whether or not special flooring, extra strength at certain points, dust-collection systems, cooling systems, humidifiers, special lighting, etc., are needed; sequence of operations and specifications for the product; material specifications; tools needed; machines needed, including the nature of the machine, its

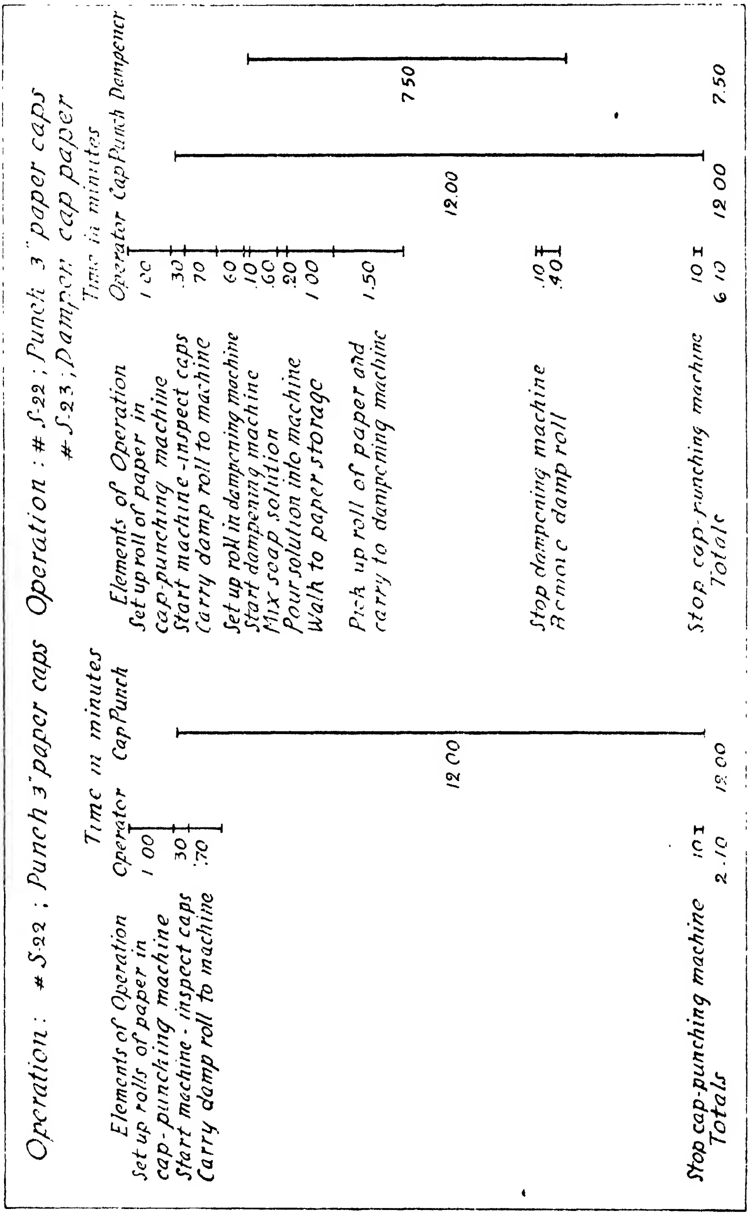


FIG. 18—Machine-and-operator time chart.

weight, the greatest space it will require for operation, and the allowed time for normal operation, if time studies are available, or if not, its rated capacity; the type and quantity of conveying equipment; types and number of benches; and any other information which appears pertinent to the problem. Although it is considered wise to use standard conveying equipment, it often is better to use special bench equipment, designed and built for the uses to which it is to be put. The reasons for using special benches will be apparent after reading Part IV.

Of course much of this supplemental information cannot be obtained for the asking; it must be calculated or estimated by the layout man. The number of machines for a given process must be determined from the relationships among (1) the estimated quantity of a given product to be manufactured in a given period (say one year), (2) the number of hours during the period the machine or machines will be operated, and (3) the normal speed of each machine of the type needed to perform the given process, normal speed being secured from time studies or by using (customarily) 80 per cent of the rated capacity of the machine. As for the quantity of conveying equipment needed, this will depend partly upon the final arrangement of the plant, and is a matter which cannot be determined in advance.

It is helpful to put all needed data in some logical order by which they may be utilized readily as the paper layout progresses. One method[1] is shown in Figure 19. The operations are described in the first column in the sequence in which they are performed. In the second column are listed the names of types of machines which perform the required operations. The third column shows the allowed speeds taken from time studies or from data furnished by the manufacturers of the machines. If it is assumed that 1,000 units will be the greatest amount of product made in one hour the number of machines needed of each kind can be found by multiplying the allowed time per unit by 1,000. For instance, the first operation requires 0.0007 hours to process

[1]See Maynard, Harold B., and G. J. Stegemerten, *Operation Analysis*, p. 244.

one unit, and 0.0007 times 1,000 equals 0.7. This figure is placed in column four. One machine, operated seven-tenths of the time will handle the expected output of the plant. The second process requires 0.02 hours per unit and this figure times 1,000 equals 20, the number of machines required for operation number two. And so on.

Operation	Machines				Temporary Storage	Operator Time	Machine Time
	Name and Kind	Allowed Speed	Number Needed	Floor Dimensions			
# 1	A	07 Hrs/100 Units	07	2' x 15'	None	.03	.04
# 2	B	2 00 Hrs/100 Units	20.0	5' x 10'	10' x 20'	.50	1.50
# 3	C	.12 Hrs/100 Units	1.2	10' x 12'	Bin 6' x 6'	.12	.12

FIG. 19—*Layout data table.*

The figures resulting from this procedure will seldom come out even. When, as in the case of operation number one, the figure is a fraction low, something extra should be found for the machine to do, if possible, in order to avoid idle time. When, as in the case of operation number three, the figure is a fraction over, an attempt should be made to reduce the allowed time by subjecting the operation to a careful motion study. So, in the third operation, an attempt first is made to reduce the standard to 0.10 hours per 100 units. This failing, it will be necessary to use two machines which will operate at only three-fifths capacity. If nothing can be found for these machines to do in order to take up the slack, a possible solution would be to use only one machine and operate it overtime long enough to avoid delaying the rest of the production line.

The actual floor dimensions of each machine are shown in column five. It is obvious that the dimensions would include all movable parts of each machine in their most extended positions. If the machine operates with material extending out beyond the limits of the machine, this distance should be included, but bins, tables, and temporary storage

space should be shown separately in column six. Space for the operator, for the aisles, and for other purposes, varies from industry to industry, and depends upon the types of conveying equipment used as well as upon other factors. The needs for such space must be taken into account, of course, when the layout is made.

The last two columns furnish data which are helpful in grouping machines for better utilization of the labor of each operator. The second operation, for example, requires 0.5 hours per 100 units of operator time and 1.5 hours per 100 units of idle operator time while the machine runs automatically. Allowed time divided by man time, in this case, gives four—the number of machines of this kind one operator theoretically can handle. Actually, walking time from machine to machine must be added and in practice it would rush one operator too much to handle four machines. In this case probably three would be grouped. Since twenty are required, eighteen could be laid out in groups of three while two would be left over. The two extra machines could easily be operated by the operator of the machine which performs the first operation, for 0.0003 hours per unit times 8,000 units (the expected production per 8-hour day) equals 2.4 hours, the time this operator would work if he handled the first process and nothing more. Out of an eight-hour day this operator would be idle 5.6 hours. The time required to handle two "B" machines for the second process would be found by multiplying the operator time per unit (0.005 hours) by the number of units to be handled by two "B" machines ($8{,}000 \times 2/20 = 800$), which is 0.005 times 800, or 4 hours. This is well within the 5.6 hours this operator had at his disposal.

Preparing the Layout.—Plans which show available space drawn to scale are secured for each floor. All obstructions are put in their proper places and labeled, and overhead obstructions, floor strengths, windows, lights, and other important features are noted. If certain installations require given positions in the plant, these, as well as the obstructions already noted, are outlined heavily on the floor plans and become fixed points around which the lay-

out must be built. These plans should be mounted with thumb tacks upon boards of soft wood.

A template for each machine, piece of equipment, and for each storage space of fixed size and shape is next cut to scale from light cardboard and properly labeled. These templates can be arranged on the floor plans in what seems to the layout man to be the most satisfactory approach to the ideal layout suggested by the operation chart previously prepared. The templates are then fastened in place temporarily, using thumb tacks, rubber cement, adhesive tape, or any other satisfactory means. The flow of materials is indicated by means of arrows or colored threads, held in place with thumb tacks or adhesives. Criticism now is invited from foremen, superintendents, and others who are interested. Such criticism often results in several changes. When no further improvements can be suggested, the layout is put in more permanent form by being photographed or otherwise copied. These copies are used for "selling" the new layout to top management, for reference purposes while the physical layout is being made, and for record purposes. Departmental layout panels frequently are hung so as to form a composite of the entire plant. As individual panels are changed they can easily be replaced so as to keep the plant layout up to date.

Immediately after the physical layout is made it often is found necessary to make minor changes, and from the day the new layout is put into effect the evolutionary tendencies that develop as time passes will begin their unceasing attacks which eventually leave the new layout as useful as a blunt tool—and the job will have to be done all over again.

Under direct-line manufacturing conditions there is always one operation that constitutes a bottleneck for the process as a whole. The analyst is under tremendous pressure to simplify the bottleneck operation, for if he succeeds in reducing the required time by only six minutes a day, and if ninety-nine operators have been idle ten minutes a day waiting for the slow operation, it is apparent that not six minutes have been saved, but 600, or ten hours. Such activity on the part of the motion-study analysts

provides one more reason why frequent layout changes must be made.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. The plant layout, as finally put into effect, reflects certain compromises. Name a few.
2. What is a flow diagram? How does it differ from a layout? How is it used by motion-study analysts?
3. Draw an operation chart for a synthetic industry. Explain how operation charts are used.
4. Draw an operation chart for an analytic industry.
5. Draw a flow chart and state what information is shown in this chart that is not shown in the operation chart. How are flow charts used by the analyst?
6. Draw a machine-and-operator time chart and explain its use.
7. Why should there be any objection to the grouping of machines for better labor utilization?
8. Why, in your opinion, does the analyst consider it good practice to use special bench equipment?
9. If the figures indicate that 2.1 machines are needed for a given process, what alternatives are available to avoid the necessity of providing three machines?
10. Describe the process of making the final paper layout. Why can the machine positions not be laid out mathematically and drawn correctly the first time?
11. Why is the compulsion to reduce the time required to perform the slower jobs usually great under conditions of direct line production?

PART IV

MOTION ECONOMY

Chapter 11

THE WORK CYCLE

The ultimate objective of business is that of furnishing goods and services, at a profit, to the public. The ultimate objective of motion economy is to assist business enterprise to make larger profits by discovering better ways of performing manual work. The motion-study analyst is not actively concerned with how these profits are shared among stockholders, landlords, managers, employees, and customers; this is a matter which management undertakes with varying degrees of compulsion, depending upon the operation of the laws of economics and self-preservation in individual cases. Perhaps some analysts would do better work and take more pride in their profession if the ultimate objective of motion economy were stated differently —relieving mankind from drudgery, improving the surroundings of laborers, or aiding managers and workers to cooperate. In spite of the fact that many of these more idealistic objectives are often attained in practice, the fact remains that the ultimate objective is to assist in the creation of greater profits. There is no reason why the analyst should be ashamed of his role in profit-making, for under our pecuniary economy the normal, unsubsidized business concern lives at the mercy of profits and dies when they cease. Under such a system, the business manager scrutinizes each expenditure from the standpoint of its profit-making possibilities. Every dollar spent which does not ultimately come back to the firm, bringing with it at least some increase, is, from a business viewpoint, badly spent.

THE MACHINE DESIGNER COMPARED WITH THE ANALYST. —In spite of the fact that it might be said that the ultimate objective of the machine designer is identical with that of the analyst, there is a difference in their aims. The

difference is chiefly one of emphasis. The machine designer, for example, seeks to enhance the profits of the business by creating a machine which does the work of many laborers. Although the amount of labor per unit of product is less, the amount of labor performed by each individual who works in a given plant could be greater after machinery is introduced than before. The machine designer could, for instance, put the controls in such positions as to require operators to expend their energy to poor advantage. Such designers would be reducing labor in the aggregate, but individual workers would be forced to work harder. The analyst, on the other hand, is interested in reducing the amount of work performed by the individual. He does this by rearranging the workplace so as to systematize the operations performed, by finding the reasons for hesitation and eliminating them, by using mechanical aids, and by attaining the other objectives discussed in this chapter. The machine designer is interested in the mechanical performance of certain operations. He leaves such matters as ease of operation, efficient feeding, and ready disposal of the produce of the machine to the motion-study analyst. Analysts do not design machines; they see that individuals work easily and naturally, but effectively, without wasting time or energy. The machine designer perfects ideas for the mechanical accomplishment of operations; he is not interested in how individuals spend their time or the means they employ in the performance of their tasks.

THE WORK CYCLE DEFINED.—In order to attain his ultimate objective, the analyst seeks to reach certain secondary objectives. But before listing these and detailing the means by which they may be put into effect, it is necessary to understand the nature of the work cycle. A work cycle consists of all of the operations necessary to complete a given job for a given number of units. In order to determine what a cycle is, it is necessary to define the job as well as to specify exactly what unit of production is involved. A few illustrations will make this clear.

Four workers comprise a gang which packs soap powder by hand in 8-ounce cartons which, in turn, are packed

sixty to a box. One, a man, keeps three girls supplied with powder, cartons, and boxes. He also glues and trucks away the packed boxes. The first girl makes up the cartons, opening up the collapsed "shells" and gluing the bottom flaps. The second girl fills and weighs cartons. The third girl glues the top flaps of filled cartons and packs them in the boxes. A "job" could be defined in a number of ways. Getting boxes could be a "job." A cycle could consist of all necessary operations involved in getting one truckload of boxes from the storeroom. Such necessary operations as greasing the truck, looking for extra trucks, moving obstructions from the way to get at the particular size of box needed, etc., would be included—and just that proportion of such "extra" or infrequent parts of the job would be included as would cover the number of boxes that could be comfortably loaded on one truck. If 1,000 boxes could be carried on one trip, one cycle would be the total amount of work required to get 1,000 boxes. Setting up cartons could be considered as being a "job." All work incidental to setting up one carton could be considered as being a cycle: getting and mixing glue, opening and gluing bottom flaps, placing on bench, etc. Likewise, each of the other individuals could be considered as handling one or more jobs—but a "job" could be, also, the entire amount of work done by the gang as a whole. If, with the job so defined, the unit were defined as one box of sixty cartons, a cycle would be all necessary work reduced to a "per box" basis, from getting boxes, cartons, powder and glue, to trucking the packed product to the warehouse. Work cycles must be properly defined before accurate time studies can be made, and cycles are considered again in connection with that subject in Chapter 17.

The work done in the wider cycles, work which is studied less intensively by the analyst, has formed the subject matter of Parts II and III of this book. The term "motion economy" refers to the work done by motion-study analysts in connection with the improvement of work methods within relatively narrow cycles. In studying the narrow work cycle, the analyst finds it useful to break it down into its "elements," in order to make improvements.

COMPONENTS OF THE WORK CYCLE.—Ever since the days of Frank B. Gilbreth, analysts have recognized the need for reducing manual operations to elements which are common to all. After such elements have been defined it is possible to make generalizations concerning them, which will apply universally to all jobs of the narrow-cycle nature which are being considered at this point. Unfortunately, there is considerable disagreement among writers in defining these elements—a condition which exists because the subject has not reached a very high degree of development. The Gilbreths and their assistants called these elements "therbligs" (the name Gilbreth spelled backward). But regardless of the name by which they are called—therbligs, constituents, elements, components, basic divisions, etc.—it is vital to the motion-study analyst that they be thoroughly understood and put to use.

Following the lead of the Gilbreths, many writers have modified, added to, and subtracted from the list of elements, a process which has been continued by the present writer, not with the desire, however, merely to be different, but with a sincere desire to present a system freed of many of the objections which have been leveled at the conventional list of therbligs. The chief objections to the conventional system of classification are: (1) a large proportion of these so-called elements are not mutually exclusive, and (2) they do not lend themselves to clear definition. All of the Gilbreth terms are retained except for one: "manipulate." This term was adopted in order to reconcile the misunderstandings that have arisen concerning the precise nature of the therbligs "use," "assemble," and "disassemble." However, some of the therbligs are removed from positions in which they masquerade as elements, and are relegated to the role of modifiers or adverbs descriptive of certain therbligs which are more elemental in nature. The divisions used by the writer are not therbligs. The therblig terms are retained, but the basis on which the classification is made is so different that it was felt that a different name should be used. The name "component" is concise, and it has the advantage of being readily understood.

The work cycle is divided into eight components. (See Table 1.) Three of these components are not subject to modification, one is subject to a series of primary modifiers, and four are subject to primary and secondary modifiers.

TABLE 1. Components of the Work Cycle

Components	Abvns.	Modifiers: Primary	Abvns.	Secondary	Abvns.
1. Transport	T	Empty	TE	Pre-position	TEP
				Roundabout	TER
				Pre-position and Roundabout	TEPR
		Loaded	TL	Pre-position	TLP
				Roundabout	TLR
				Pre-position and Roundabout	TLPR
2. Grasp	G	Selective	GS	Eye-fixation	GSE
		Non-selective	GN	Eye-fixation	GNE
3. Hold	H				
4. Position	P				
5. Manipulate	M	Assemble	MA	To Material	MAM
				To Tool	MAT
		Disassemble	MD	From Material	MDM
				From Tool	MDT
6. Release	R				
7. Inspect	I	By Ear	IE		
		By Feel	IF		
		By Odor	IO		
		By Sight	IS		
		By Taste	IT		
		By Kinesthesis	IK		
8. Delay	D	Avoidable	DA		
		Unavoidable	DU	Balance	DUB
				Nerve Reaction	DUN
				Plan	DUP
				Rest	DUR
				Search-Find	DUS

TRANSPORT.—The component "transport" is not used without one or the other of its primary modifiers. "Transport, empty" describes the act of reaching for an object, either with the empty hand or with a holding device, such as tongs, a ladle, a movable holder in a machine, etc. It usually follows the component "release" and ends with "grasp." "Transport, empty, pre-position" describes the act of turning the empty hand or empty holding device so as to put it in position for grasping an object. "Transport, empty, roundabout" means that the hand, or empty holding device, has detoured around an obstacle. Occasionally it is necessary to describe the act of moving the empty hand or holding device in a roundabout manner, turning it en-route in order to put it into position for grasping. This component is "transport, empty, pre-position, roundabout."

"Transport, loaded" describes the act of moving an object. It begins the instant the hand or device begins moving the object and it ends when the object is released. This component does not necessarily follow "grasp" although it usually does. Frequently objects are slid or pushed along a conveyor, in which case "transport, loaded" is used immediately following "transport, empty," no "grasp" being involved. The use of the secondary modifiers "pre-position" and "roundabout" is similar to that described in connection with "transport empty."

GRASP.—The component "grasp" is either "selective" or "non-selective." If the fingers (or mechanical device) must grasp one or more objects from among a number of other objects, either similar or different, arranged in such a manner that these other objects constitute interference, and cause fumbling and increased work, the act is called "grasp, selective." If, however, the objects grasped are so presented as to enable the fingers (or other means) to grasp the exact number of objects (one or more), without interference from other objects, the act is "grasp, non-selective." If eye fixations are necessary the components are "grasp, selective, eye-fixation" or "grasp, non-selective, eye-fixation." This component begins as the finger (or mechanical means) touches the object and ends when complete control has been attained. As a rule this component

is preceded and followed by the two modifications of "transport": "transport, empty" and "transport, loaded."

HOLD.—The component "hold" is difficult to explain, though in practice it usually is not difficult to detect. Gilbreth originally intended that "hold" should be a continuation of "grasp." The validity of this concept is most apparent in describing such an act as grasping an ink bottle with one hand and, without moving it, retaining the grasp while the other hand removes the cap. Under such conditions it would be impossible to determine the precise instant "grasp" ended and "hold" began. But analysts have been confronted more frequently with a slightly different situation: one hand travels empty to the ink bottle (TE), which is grasped (G) and transported to a more convenient location (TL), at which point the other hand removes the cap. Strictly speaking the original grasp persists until the bottle is released. "Transport, loaded" could be considered as being a modification of "grasp," as could, also, "inspect," "position," "manipulate," and "delay," under some conditions. But the character of a retained grasp is so different from the initial act of acquiring control (as is the nature of the problem confronting the analyst in improving each act) that it is considered wise to separate the initial phase from the retentive phase. "Hold" has been defined as the act of retaining control over an object after it has been grasped. This definition obviously includes "transport, loaded," "position," "manipulate," and certain "delay" modifications. Another writer adds the qualification that no movement should take place. This removes some of the confusion but it still does not define the component satisfactorily. Everyone has, at one time or another, screwed a nut onto a bolt. The two hands probably reached for the bolt and nut and grasped them simultaneously. When the hands were in a comfortable location one of two actions took place: either one hand retained control over the bolt and the other positioned the nut and turned it, after which a succession of releases, pre-positionings, grasps, and turns occurred until the nut was in the proper position, or, one hand retained control over the nut while the other positioned and turned the bolt into place. In

neither case could it be said that no movement took place in the part that was being "held." Nevertheless, the component "hold" is present in each case. If, however, neither hand releases its grasp, both being active in positioning and engaging the threads, and if no more than a one-half or a three-quarters turn is required in order to screw the part on tight (as is the case in assembling a fountain pen and its cap), no "hold" would be present. The component "hold" is seen, then, as the retention of control over an object in which any movement which may be present is incidental and subordinate to the main function which, for the duration of the component, is performed by the other hand or by a tool. If a part is held under a drill the component is "hold," but if the part is held against a buffer the component is not considered as being "hold" because, although the buffer is spinning, the part must be moved so as to bring the tool into contact with various parts of the surface—and in this case the act of holding is active, not passive, in nature. If, however, the left hand holds a block while the right hand rubs sandpaper on it, the act performed by the left hand is described by the component "hold," for the right hand is the active, controlling agent and the left hand is passive.

Position.—The component "position" usually is the end of the act of bringing an object into exact relationship with another, preparatory to assembly or use. The act of carrying a threaded bolt to a tapped hole is described by "transport, loaded," but when the hand slows to almost a standstill and begins to bring the bolt into exact alignment, the component "position" begins. It ends when the threads have engaged and the act of turning the bolt begins.

Manipulate.—The component "manipulate" includes the acts of using, assembling, and disassembling. The act of filing would be described as "manipulate" without qualification, as would the acts of drilling, buffing, and grinding. If one object is placed into or attached to another this component is qualified, and the act is described as "manipulate, assemble." As a rule the component is not used, however, in this form—it is further qualified. If the object is placed in a fixture the component is "manipulate,

assemble to tool"; and if the object is, say, a bolt being screwed into a hole in another part, the act is described as "manipulate, assemble to material." Likewise, if an object is removed from a fixture, the component description is "manipulate, disassemble from tool"; and if a bolt is unscrewed from another part, the component becomes "manipulate, disassemble from material."

RELEASE.—The component "release" is a very short one. It is the reverse of "grasp" and it begins when the fingers (or mechanical device) begin to relax control over an object, and ends when the fingers (or mechanical device) lose contact.

INSPECT.—The act of comparing a quality of an object with a predetermined standard is described by the component "inspect," which is never used without its modifiers. Inspecting a sewing machine by listening to it run in the silent room is "inspect by ear"; inspecting for burrs by rubbing the finger over a part is "inspect by feel"; inspecting hams by pushing an ice-pick into them and smelling them is "inspect by odor"; inspecting a part for defective color is "inspect by sight"; inspecting coffee, tea, and food products by tasting is "inspect by taste"; and inspecting for weight by lifting an object, or testing the resistance of a mass to pressure, or checking the tightness of a screw or nut by applying muscular effort, would be "inspect by kinesthesis." Resort to a dictionary discloses the fact that kinesthesis is the sense of muscular effort. The colloquial term "heft" is expressive, but it cannot be applied to testing the tension of a taut wire or the resistance of a mass of material when squeezed in the hand. Although there is a distinct difference between "inspect by feel" and "inspect by kinesthesis," it is easy to confuse the two. When the sense of touch is employed, there is little or no muscular resistance. On the other hand, the operator who lifts a box to test its weight is interested in the way it feels to his muscles and joints, not in the way it feels to the nerve ends in his fingers and hands.

It is possible, of course, to use more than one sense at once. Hams may be inspected by sight and by odor, in which case the component would be "inspect by sight and

by odor"; and burrs or scratches may be detected by combining touch and sight—"inspect by feel and by sight."

DELAY.—The component "delay" is not used unmodified; it is either avoidable or unavoidable. When the present method is being described, the status of "delay" should be considered on the basis of the operation as it now is. It is not correct to say that a delay would be avoidable *if* a change in the operation were made, and that, therefore, the delay *under present conditions* is avoidable. Such a delay should be described as unavoidable. But if a *proposed* method is being charted, this component should be considered unavoidable only after the most searching efforts have been made to eliminate it.

When motion ceases for no good reason, the component is "delay, avoidable." All unavoidable delays are further qualified in order to indicate the reason. If the operation, as it is being performed, necessitates one hand waiting for the other, the component is "delay, unavoidable, bal-

LEFT		10,000ths. of an hour		RIGHT	
Explanation	Components			Components	Explanation
	DUB	5	2	TEP	To box
To paper	TE	2	6	GSE	Pencil
			2	TLP	To paper
			2	P	At upper left-hand corner
Paper	H	28			
			23	M	Write
To original position	TE	2	2	TL	To box
	DUB	3	1	R	Pencil into box
			2	TE	To original position

FIG. 20—*Simo chart. Writing with a pencil.*

ance." If the hand, for instance, must move quickly in response to a stimulus, such as a click, there is an appreciable delay from the time the sound is heard until the hand begins to move. This delay is described by the use of "delay, unavoidable, nerve reaction." Hesitation in order to check with the blueprint or to recall a dimension in the specifications would involve planning, and the component would be "delay, unavoidable, plan." If rest is required as a result of sustained exertion, the pause would be described as "delay, unavoidable, rest." And if the operator stopped to look for a lost tool or part, the delay would be described as "delay, unavoidable, search-find," a component which should not be confused with "grasp, selective," which describes a situation in which nothing is lost and in which increased exertion results, rather than delay.

THE SIMO CHART.—The eight components and their primary and secondary modifiers are used to describe work methods. When the abbreviations are used to record ex-

LEFT		10,000 ths. of an hour		RIGHT	
Explanation	Components			Components	Explanation
To paper	TE	2	2	TE	To pen
			1	GNE	Pen
			2	TL	To paper
			2	P	At upper left-hand corner
Paper	H	31	26	M	Write
To original position	TE	3	2	TL	To holder
			2	P	In holder
	DUB	4	1	R	Pen
			2	TE	To original position

FIG. 21—*Simo chart. Writing with a pre-positioned pen.*

LEFT				RIGHT	
Explanation	Components	10,000ths of an hour		Components	Explanation
To part	TE	2	2	TE	To pile of screws
Part	G	2	4	GS	Screw
"	TLP	4	2	TLP	"
			3	P	"
			7	MAM	Start screw
			1	R	Screw
			12	DS	Screwdriver
	H	47			
			4	TEPR	Screwdriver-obstacle
			2	G	Screwdriver
			4	TLPR	Screwdriver-obstacle
			4	P	Screwdriver
			10	MAM	
"	TL	2	2	TL	"
"	R	1	1	R	"
To original position	TE	2	2	TE	To original position

FIG. 22—*Simo chart. Assembly operations.*

actly what each hand did, and the time required for each component is indicated along vertical lines, the resulting chart is known as a left and right hand, or "simo" (for simultaneous), chart. A few illustrations of simple operations are shown as follows:

The act of taking a pencil from a box of pencils, writing, and replacing the pencil with the right hand, while the left hand holds a sheet of paper, is charted in Figure 20.

Figure 21 shows the act of taking a pre-positioned pen (desk set) from the holder, writing, and replacing it.

Figure 22 charts the following operations: picking up and holding a part with the left hand, picking up and putting a screw in place with the right hand, and tightening the screw with a screwdriver held in the right hand.

CLASSIFICATION OF MOTIONS.—It is customary among

motion-study analysts to speak of motions which involve only the fingers, as first degree motions; those which involve wrist or ankle motions, as second degree; those which involve elbow or knee motion, as third degree; those which involve hip or shoulder motion, as fourth degree; and those which involve waist motion, as fifth degree. This motion classification system is used on the simo charts as follows:

The act of picking up a machine part from the floor is charted in Figure 23.

LEFT		10,000ths of an hour		RIGHT	
Explanation	Components			Components	Explanation
			5	TER 5°	To part on floor
	DUB	12	2	G 1°	Part
			5	TLR 5°	To center of bench

FIG. 23—*Simo chart with motions classified. Getting a part from the floor.*

Figure 24 charts the act of sliding a part with each hand from a position twelve inches in front of the operator to a position three inches in front of him.

LEFT		10,000ths. of an hour		RIGHT	
Explanation	Components			Components	Explanation
To bin	TE 4°	2	2	TE 4°	To bin
To fixture	TL 4°	3	3	TL 4°	To fixture

FIG. 24—*Simo chart with motions classified. Sliding parts to position for assembling.*

The act of positioning and starting a screw and tightening it with a screwdriver is charted in Figure 25.

MAKING SIMO CHARTS.—Simo charts can be made most easily and accurately from motion pictures of one or more cycles of a given operation. They are often made, however, from direct observation of the worker. In either

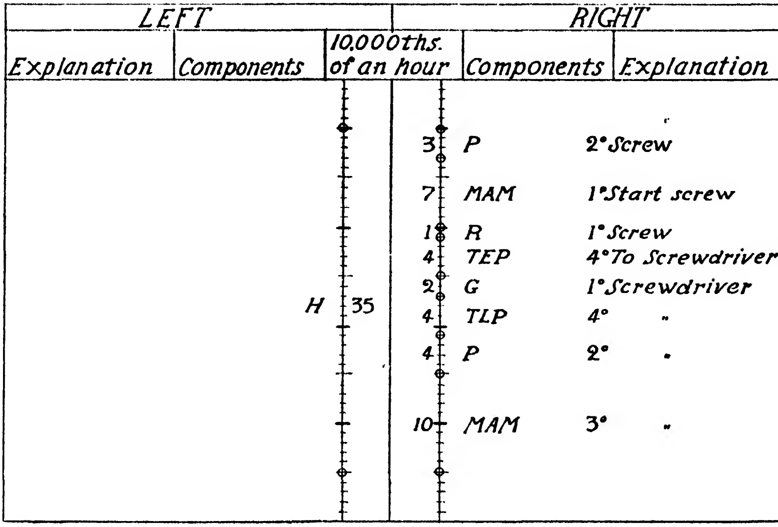


FIG. 25—*Simo chart with motions classified. Assembly of screw to part.*

case, it is customary to chart, first, all of the left hand motions for the cycle, after which the right hand motions are charted. When charts are made from direct observation of the worker, the times required for the longer components and for the entire cycle are timed with a stop watch or with a pocket watch, but the times for the shorter components are estimated.

The question usually arises, in connection with the construction of simo charts, as to the procedure of charting such operations as walking, driving a truck, etc. Some writers have even applied the terms "transport empty" and "transport loaded" to such operations. While the present writer sees no objection to such a procedure, he feels that there is little to gain by it. The components should be confined, as a rule, to bodily motions, and hence, should be used only in connection with simo charts. So to return to the question, walking and driving a truck should be described on a flow chart or flow diagram. If, for instance, a man walks to the storeroom for parts and tools, then returns and assembles the parts, he is performing a task

which should be broken down, for purposes of analysis, into two sections. Walking for parts and tools, waiting at the tool crib, walking back, and placing them on the bench, are operations which should be studied in connection with plant layout. The flow chart, flow diagram, and operation chart all are useful in this connection. The assembly of parts should be described by means of a simo (left and right hand) chart. Occasionally it is necessary to chart such operations as operating a yard locomotive, tractor, traveling crane, or truck. Such jobs should occasion no difficulty to the analyst if he ignores the functions being performed by the machine and describes only those performed by the operator. Thus, reaching for the control which closes the jaws of a bucket conveyor around a load of coal is "transport empty"; grasping the control is "grasp"; using the control is "manipulate." Analysts have become confused in the use of components and simo charts when they analyzed the motions of the *machine* instead of those of the operator. It should be kept in mind that the motions of the *operator* are being studied and improved. If this is kept in mind, another source of confusion will be removed: namely, that involved in the use of tools. An operator, for instance, reaches for a pair of pliers, picks them up, transports them to a heated wire, picks up the wire with them, and transports the wire to position. In the case of the crane, the functions performed by the machine had little or no connection with the motions performed by the operator; but when small tools are used, the functions they perform are closely related to the motions performed by the operator. The above operation should be described as follows: TE, GN, TL, GN, and TL. Under "Explanation" on the simo chart, the following words should be written opposite each of the successive abbreviations: "To pliers," "Pliers," "Pliers," "Heated wire," and "Heated wire." Some analysts will argue that if pliers are an extension of the hand and are treated as such on the simo chart, a steam shovel, likewise, should be considered as an extension of the hand. There is, however, a real difference. In the case of the hand tool, the hand performs a grasping motion as the pliers grasp the

wire, and, as the wire is transported, the arm moves just as it would if the fingers were holding a cold wire and no pliers were being used. But when a bucket conveyor picks up a load of coal and moves it, the hand of the operator does not perform a grasping motion as the load is grasped by the machine; the hand may hold a control, or even rest, while the machine transports the material.

The common term "left and right hand chart," for simo chart, is a bit unfortunate in that other bodily members are often used for actuating controls. In driving a car, for instance, the feet do most of the work. They start the motor, operate the clutch, regulate the speed, operate the brakes, and dip and raise the headlights, while the hands steer and turn on and off the ignition, headlights, parking lights, windshield wiper, heater, etc. On the later models, the function of shifting gears has been given back to the feet. The automobile has been used as an illustration because analysts frequently encounter objections by workers to new methods which employ the use of pedals. One such operator, good naturedly but in a sarcastic tone of voice, asked an analyst who had introduced two new foot controls, why one of the controls could not be tied to him so as to be actuated by a twisting motion of his hips. The housewife guides the material she sews through her electric sewing machine with her hands, while she controls the speed of the motor by pressing her knee sidewise against a lever. Controls are operated, often, with elbow, arm, wrist, finger, heel, or leg. When it is desired to chart other body members than the hands, separate time scales are provided, each clearly labeled at the top.

The use of colors on simo charts helps to make comparisons between alternate methods and often helps to "sell" a new method to workers and managers. Vertical columns are provided on either side of the time scale. Each component is measured on the time scale and the time is extended across the color column. If the spaces corresponding to the components are colored with distinctive colors, the eye and mind can grasp more easily the significance of the chart. If, for any reason, colors cannot be conveniently used, various patterns in black and white can

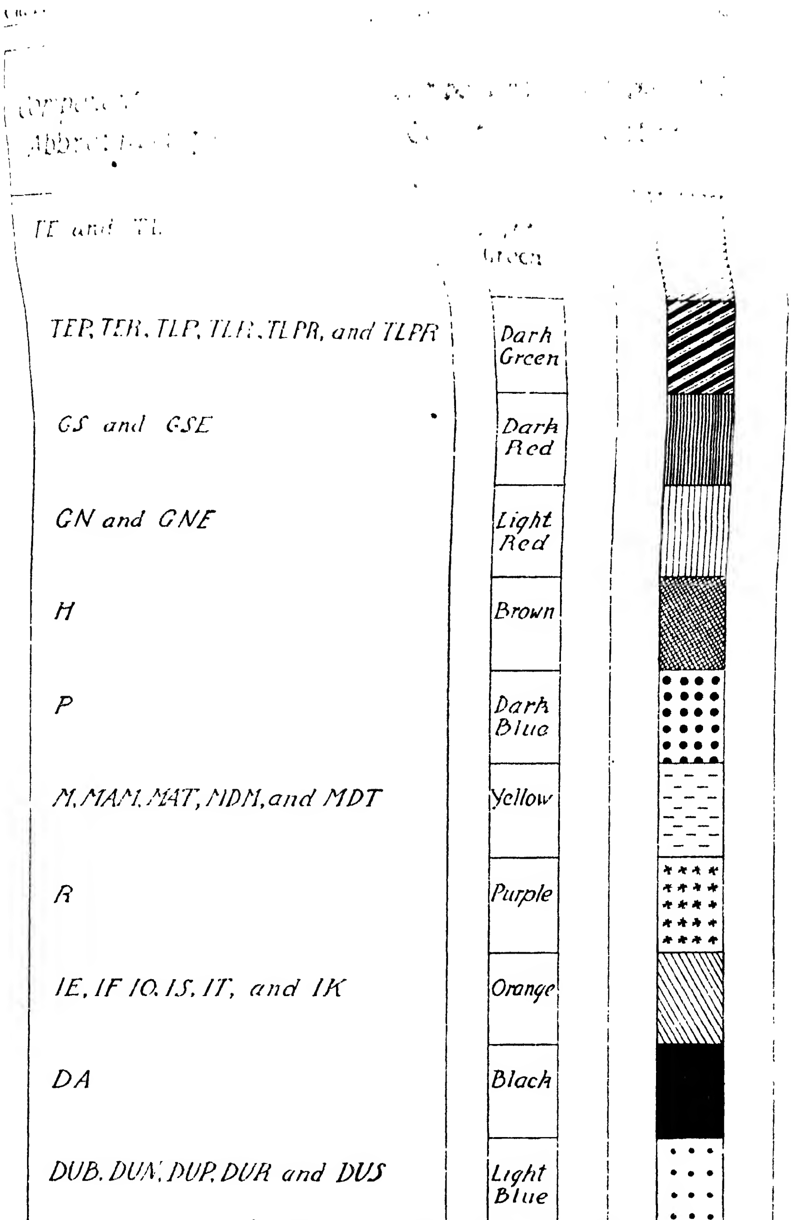


FIG. 26—*Suggested patterns and colors for simo chart construction.*

be substituted. In using the colors and patterns in Figure 26, the analyst will find that as he improves an operation, and as he charts successive methods, the successive charts become more pleasing to the eye. Operations which require the worker to hold, position, pre-position, go around obstructions, grasp selectively, and release, and which introduce delays into the cycle, will produce a dark chart. Every improvement introduced into the operation tends to make the chart lighter.

Not only are the charts of improved operations lighter, they are more symmetrical and shorter. Care should be taken to make "before" and "after" charts comparable. It frequently happens that in the old method one unit of the product is processed for one cycle, while in the improved method two or more units are processed. For a correct comparison, each simo chart should be constructed for the same number of units, i.e., two cycles of the old method (one unit processed per cycle) should be compared for length with one cycle of the new method (two units processed per cycle).

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What is the ultimate objective of business?
2. Do business concerns ever spend money with no thought of return?
3. State clearly the difference in the aims of the motion-study analyst and the machine designer.
4. Explain by means of an illustration what a work cycle is.
5. Name the eight components of the work cycle.
6. Why is it desirable to divide a work cycle into its component parts?
7. Explain clearly the following modifications of the transport component: TLP, TLR, and TLPR.
8. Explain the difference between GS and DUS. Between GS and GN.
9. Explain clearly the following modifications of grasp: GS, GN. GSE, and GNE.
10. Explain clearly the component M and its modifications MA and MD.

11. The present layout of a bench necessitates one hand waiting for the other while performing an assembly operation. A simple change would eliminate this waiting time. Is it correct to consider the observed delay avoidable (DA)?

12. Describe the simo chart and state its purpose.

13. Motion-study analysts classify motions into five degrees. Describe this system and state how it is used.

Chapter 12

MOTION ECONOMY OBJECTIVES

Keeping in mind that the ultimate goal of motion study is that of increasing profits through the increased effectiveness of manual operations, how may that goal, specifically, be attained? In theory, if the analyst wishes to increase the effectiveness of manual operations he must bring about certain changes in existing arrangements and methods until certain ideals have been realized. These ideals form the objectives toward which the analyst works. The reader should again be warned that all of the objectives stated cannot, as a rule, be achieved in any given situation; they must be chosen with discrimintion and with the realization that savings must exceed expenditures.

MOTION ECONOMY OBJECTIVES.—The objectives of motion economy are an outgrowth of Frank B. Gilbreth's rules for motion economy and efficiency,[1] which have been modified and elaborated by subsequent writers in the management field. Further modification has been made, herein, along the following lines: (1) the writer has deliberately attempted to avoid the implication that these objectives are basic "principles" or "laws," (2) the form of classification used has separated "objectives" from "suggested means for putting the objectives into effect," clarifying a confusion which rather generally exists in management literature, and (3) the objectives are expressed in terms of the components of the work cycle, with the exception of a few objectives which properly belong to the cycle as a whole. Some of the suggested means can be employed in connec-

[1]These rules may be found in Donald, *Handbook of Business Administration,* 1931, p. 640 ff.

tion with more than one component, hence, in listing them, there is some duplication.

CHECK LIST OF MEANS OF ACCOMPLISHING OBJECTIVES.— The following check list will be especially useful to beginners in motion analysis. Experienced analysts will find it useful for operations which cannot be improved by a cursory study. It is used in the following manner:

1. Make a simo chart of the present method of performing the operation.
2. Start with the longest component; find it on the check list. Components are numbered with Roman numerals.
3. Attempt to reach each of the objectives listed. Objectives are listed opposite capital letters.
4. Under each objective are listed, opposite Arabic numerals, the means by which that object can be attained. Examine each of the means listed to see if it is practicable in the present situation.
5. Check the objectives which apply to the entire cycle (IX), and determine whether or not the suggested means of accomplishing these objectives are applicable.
6. Sketch a proposed bench layout, or sketch the positions of the proposed machine controls.
7. Make a tentative simo chart for the proposed method.
8. Submit proposed method to interested workers and supervisors. Care should be taken not to ask for criticisms, for this makes it more difficult to put the new method into effect. State, rather, that this is the new method the workers or supervisor helped to develop. Show skepticism concerning its practicability, and let operator and supervisor "sell" you (and incidentally themselves) on it.
9. Submit proposed method to management for approval and authorization. (See Chapter 22 for details concerning this step.)
10. Provide required equipment, jigs, fixtures, tools, and bench layouts.
11. Train operator in new method.
12. Secure accurate simo chart of new method by means of watch (or moving picture film) analysis.

In the following outline Roman numerals (I, II, III, etc.) indicate components (IX indicates the cycle as a whole),

capital letters (A, B, C, etc.) indicate the objectives to be attained, and Arabic numerals (1, 2, 3, etc.) indicate the means suggested by which the objectives might be attained. The list does not purport, of course, to be exhaustive. Some of the suggested means of attaining the objectives do not require special physical facilities, but many of them do. These physical facilities and special arrangements are discussed in Chapters 13, 14, 15, and 16, and the reader is referred by page numbers, in the following outline, to the appropriate discussions.

I. TRANSPORT.

A. Unnecessary transport motions should be eliminated.

1. Use drop delivery conveying devices to eliminate the necessity for lifting the finished part aside. (See p. 162.)
2. Transport more than one part at a time. (See p. 163.)
3. Use a jet of air or other mechanical means to propel the part into position for use, and out of position when the operation has been performed on it. (See p. 164.)
4. Use overhead spring or counterweight suspension for tools. (See p. 175.)
5. Provide combination tools. (See p. 176.)
6. Hold continuously small tools which must be used repeatedly.
7. Increase the number of operations performed by one person. (See p. 164.)

B. The total distance covered by the hands in perform- the operations in a given work cycle should be reduced to a minimum.

1. Use mechanical or gravity conveying devices. (See pp. 162 and 164.)
2. If the product does not lend itself to the use of drop delivery, so locate the point at which the finished product is deposited that cne continuous mo-

tion can be used to dispose of it and secure the first part for the next cycle.
(See p. 182.)

3. Bins, tools, and controls should be placed so as to reduce unnecessary reaching.
(See p. 182.)
4. Use overhead spring or counterweight suspension for tools.
(See p. 175.)
5. Use a swivel fixture to hold objects that must be worked on in different positions.
(See p. 172.)
6. Place the object on which the work is being done at a point and in such a position as to reduce the distance traveled by the hands.
(See p. 182.)
7. Fixtures should be so constructed as to permit direct, instead of roundabout, motions in loading and unloading them.
(See p. 172.)
8. Barriers in the most direct paths, which cause roundaboutness of motion, should be removed.

C. Motions involving the component "transport" should be confined to those distances, classes, and paths which, in the long run, will produce in the operator the greatest feeling of naturalness and freedom of motion, and the least amount of fatigue.
   1. Operations requiring vertical motions should be balanced so as to allow the left hand to rise while the right hand falls, and vice versa.
   2. Transports involving motions to either side of the operator should be made by simultaneously extending the hands away and bringing them together over symmetrical paths; transports involving motions to the front of the operator should be made by alternately extending one hand then the other; but transports involving motions in the intermediate zone can be made either alternately or simultaneously.
   3. Lay out the workplace so that curved paths may

be followed instead of paths involving sudden changes in direction.

4. Place chutes, bins, and other conveying devices, so as to deliver materials at those points in the normal work region where the operator can most easily get them.
   (See p. 182.)
5. Place the object on which the work is being done at a point and in such a position as to reduce the distance traveled by the hands.
   (See p. 182.)
6. Provide fixed stations for tools at those points within the work region where they can most easily be reached.
   (See p. 182.)
7. If drop delivery cannot be utilized, the finished product should be deposited at a point in the normal work region which can most easily be reached.
   (See p. 182.)
8. Locate controls at those points within the normal work region where they can most easily be used.
   (See p. 182.)
9. Barriers which cause unnatural roundaboutness should be removed, or the workplace should be rearranged in order to nullify their bad effects.
10. Lay the workplace out so that materials may be grasped in the same horizontal plane in which they are used.
    (See p. 183.)
11. Place tools in positions which permit them to be grasped in the same horizontal plane in which they are used.
    (See p. 183.)
12. Locate controls in the horizontal plane which approximates that used during most of the operation.
    (See p. 183.)

D. The amount of weight carried and the amount of resistance overcome should be reduced to a minimum.

1. Arrange the workplace so that parts may be slid into place.
   (See p. 165.)
2. Employ momentum to aid the operation.
   (See p. 167.)
3. Minimize momentum if the muscles must overcome it.
   (See p. 167.)
4. Use counterweights for heavy tools.
   (See p. 175.)

E. Transports should be as free as possible from prepositioning motions.
   1. Construct material-delivery conveyors so as to permit the delivery of parts in the same relative positions in which they are subsequently used.
   2. Construct tool-holding devices and controls so as to permit the manipulation of tools and controls in the same relative positions in which they were grasped.
   3. Construct jigs and fixtures which hold the object being worked on in such a manner as to eliminate awkward turning of parts in transit.
      (See p. 172.)
   4. Rearrange preceding operations so as to permit the delivery of parts in the most advantageous positions.
   5. Use magazines or packets of parts arranged by the vendor or by lower-paid help in the most advantageous positions for use.
      (See p. 168.)
   6. Use lower-paid help to arrange parts in the most advantageous positions at the bench where they are used.
      (See p. 168.)

II. GRASP.

A. Unnecessary grasping motions should be eliminated.
   1. Use ejectors in connection with drop delivery conveying devices, to eliminate the necessity for grasping the finished parts.
      (See p. 164.)

2. Transport more than one object at a time.
   (See p. 163.)
3. Arrange the workplace so that parts can be slid into place.
   (See p. 165.)
4. Use adequate and correctly placed lighting.
5. Keep waste materials cleared from the bench by suction or other mechanical means.
6. Provide combination tools.
   (See p. 176.)
7. Hold continuously small tools which must be used repeatedly.
8. Increase the number of operations performed by one person.
   (See p. 164.)

B. Materials, tools, and controls should be so disposed and conditions should be such as to permit ease in grasping.

1. Place bins, tools, and controls in fixed positions so that the component "grasp" can be performed without the necessity for eye fixations.
2. If eye fixations cannot be eliminated, place the objects to be grasped as near directly in front of the operator as possible so as to make excessive head and eye motions unnecessary.
3. Construct bins so that parts are delivered automatically in the correct position for use.
4. Use mechanical means of grasping, utilizing magnetism, suction, air pressure, socket attachments, adhesives, tweezers, scoops, trowels, etc.
5. Use a felt pad from which small flat parts may be easily grasped.
6. Arrange material-delivery devices, tool holders, and controls so as to allow a hook grasp instead of a pressure or friction grasp.
   (See p. 169.)
7. Use the photoelectric cell and other mechanical means of aiding selection and grasping.
8. Provide adequate and correctly placed lighting.
9. Provide a background of contrasting color.

10. Provide eye-glasses, a magnifying glass, or a mirror.
11. Provide correct conditions of temperature.

III. HOLD.

A. The component "hold" should be reduced to a minimum or eliminated altogether, so as to permit both hands to do useful work as well as to promote safety.
   1. Provide a fixture, jig, magnetic device, suction device, adhesive, friction, or stops to hold the object on which work is being done.
      (See p. 172.)

B. If holding cannot be eliminated, the strain and discomfort involved should be reduced to a minimum.
   1. Use arm or elbow rests.

IV. POSITION.

A. Unnecessary positioning motions should be eliminated.
   1. Use adjustable guides and stops.
      (See p. 169.)
   2. Construct a pantograph holder for a spiral or power-driven socket screwdriver or wrench.
      (See p. 175.)

B. Ease in positioning should be promoted by reducing controlled motions, tenseness, and fumbling.
   1. Use jigs.
      (See p. 172.)
   2. Use adjustable guides and stops.
      (See p. 169.)
   3. Arrange the workplace so that materials and tools can be placed in position more easily.
   4. Bevel, chamfer, countersink, dimple, and remove all impediments to ease and speed in positioning tools and parts.
   5. Paint backgrounds colors contrasting with those of parts and tools being positioned.
   6. Move point grasped closer to end of object to be positioned.
   7. Increase unnecessarily low tolerances.
   8. Provide adequate and correctly-placed lighting.

9. Provide eye-glasses, magnifying glasses, and mirrors.
10. Use tools employing magnetism, friction, adhesives, or suction to aid in positioning parts in relatively inaccessible places.
(See p. 176.)

V. MANIPULATE.

A. The amount of resistance that must be overcome by the muscles of the operator should be reduced to a minimum.
1. Construct controls so that slight pressure is sufficient to actuate them.
2. Construct fixtures with compressed-air power, springs, counter-weights, cams, quick-acting clamps, and other mechanical devices.
(See p. 172.)
3. Employ momentum to aid the operation.
(See p. 167.)
4. Minimize momentum if the muscles must overcome it.
(See p. 167.)
5. Provide large enough handles for controls and tools so as to reduce to a minimum the grip and force necessary to manipulate them.

B. Positions and motions which continue to be awkward and unnatural to the operator should be avoided.
1. Construct fixtures so as to permit manipulation of parts in easy, natural positions.
(See p. 172.)
2. Place controls where they can be manipulated in easy, natural positions.
3. If a substantial part of the cycle is spent doing hand assembly work, arrange the fixture so that one hand turns against the other. (Somewhat in the manner of a person facing the edge of an open door and holding one doorknob in each hand, turning one hand against the other.)

C. A given amount of time spent manipulating parts, tools, or controls should produce a maximum of results.

1. Lay the workplace out so that more than one operation can be performed at once on one part.
2. Lay the workplace out so that more than one part may be processed at once.
   (See p. 163.)
3. Provide power-driven tools.
   (See p. 175.)
4. Increase operating speeds.
5. Provide properly sharpened tools.
6. Provide the correct lubricants and coolants.

VI. RELEASE.

A. Unnecessary release motions should be eliminated.

1. Use drop delivery conveying devices, actuated by hand-operated levers, foot-operated treadles, or photoelectric cells, to eliminate the necessity for grasping, transporting, and releasing finished parts.
   (See p. 162.)
2. Transport more than one object at a time.
   (See p. 163.)
3. Provide combination tools.
   (See p. 176.)
4. Hold continuously small tools which must be used repeatedly.
5. Increase the number of operations performed by one person.
   (See p. 164.)

VII. INSPECT.

A. Eliminate unnecessary inspecting operations.

1. Combine two or more inspections.
2. Provide photoelectric cells for mechanical inspection.
3. Combine an "inspect" with a "transport" or a "manipulate."

B. The sense and the method employed in inspecting should produce satisfactory results with a minimum of time and effort.

1. Provide adequate and correctly placed lighting.
2. Provide eye-glasses and magnifying glasses.

3. Use mirrors to facilitate visual inspection at inaccessible points.
4. Weigh identical parts instead of counting them. (See p. 169.)
5. Provide stationary gauges.
6. Provide multiple gauges.
7. Provide a background of contrasting color, illuminated ground glass, or reflected light.

VIII. DELAY.

A. Delay *in the proposed method* should be considered unavoidable only after the most searching efforts have been made to eliminate it.

(DA)

1. Arrange for an uninterrupted supply of materials.
2. Keep all machines, tools, and equipment in good operating order.
3. Avoid crowding.

(DUB)

4. Arrange the workplace so that the correct hand motions can be made, and train the operator in the proper method.
5. Arrange the sequence of components so that both hands can begin and end their components at the same time.
6. Balance the work so that the hands carry approximately equal weights.
7. Speed up the machine or shorten the distance it must move so as to reduce waiting time of the operator.
8. Provide an extra fixture which can be loaded while mechanical operations are being performed.
9. Combine operations from other cycles so as to utilize idle time more fully.
10. When waiting time cannot be eliminated in any other manner, provide other work for the hands to do.

(DUP)

11. Use clearly designed and worded instruction sheets. (See p. 177.)

12. Use perspective drawings or photographs instead of blueprints.
    (See p. 181.)
13. Provide samples of products in their finished states.

(DUR)

14. Avoid excessively long working days, or allow adequate periods of relaxation during which freedom of movement is provided.
15. Provide good working conditions: correct temperature; comfortable humidity; adequate ventilation; freedom from dust, odors, and fumes; correct illumination; freedom from noise and vibration; absence of depressing colors; absence of identical uniforms; and presence of variety in style and color in clothing. (But observe safety rules.)
16. Provide eye-glasses, magnifying glasses, and mirrors to reduce rest periods for recovery from eye fatigue.
17. Provide a comfortable chair, arm rests, and foot rests.
18. Introduce regular delay periods into the work cycle for allowing rest from fatigue, if the components cannot be arranged so as to permit the use of alternate sets of muscles.

(DUS)

19. Provide fixed stations for materials, tools, and controls.
20. Use differently colored tool handles, labels, bins, sections of the bench, and controls to aid the eye in finding.
21. Provide adequate and correctly placed lighting to eliminate avoidable delay at all points in the cycle and to reduce unavoidable search-find delay.

(GENERAL CONSIDERATIONS WHICH AFFECT DELAY)

22. Provide mutually satisfactory wages.

23. Provide satisfactory employer-employee relationships.
24. Take all possible precautions for the safety of the operator.
25. Use motion pictures to explain new operations.
26. Number containers in the sequence in which their contents are used.
27. Shorten the work cycle.
28. Provide music to dissipate subjective fatigue caused by ennui.
29. Specify proper clothing and discourage the wearing of rings, bracelets, and other jewelry.
30. Use a substitute material if trouble is encountered with the one being used.
31. Determine, and attempt to correct, the reason for worry, absent-mindedness, antagonism, or lack of interest on the part of the operator.
32. When eye fixations are necessary, put objects to be grasped as near in front of the operator as possible.
33. Select operators so as to obtain those best fitted for the jobs they perform.
34. Provide incentives in the form of increased compensation, bonuses, prizes, public recognition, competition, etc., for increased productivity.

IX. THE ENTIRE WORK CYCLE.

A. As many as possible of the usual components of the work cycle should be eliminated.
   1. Provide adjustable jigs and fixtures, constructed as simply as possible.
      (See p. 172.)
   2. Provide a moving conveyor, either continuous or intermittent, on which the operation can be performed.
      (See p. 164.)

B. The hands should be relieved of as many components as possible.
   1. Give some of the components to the feet, knees, or elbows to perform, provided the hands perform other necessary components simultaneously.

C. The components of the work cycle should be so distributed as not to overwork any one set of muscles.
   1. Allot the work among the body members and muscles capable of performing it in proportion to their abilities.

D. Rhythm should be present in order to secure smooth performance of an operation.
   1. Arrange the work in such a way (a) that emphasis can be placed upon certain recurring motions, (b) that such emphasis or "beat" repeats at approximately equal time intervals, (c) that there are an even number of beats to a cycle,[2] and (d) that there are not fewer than four beats to a cycle.
   2. Arrange the sequence of motions so that fatiguing components are followed either by periods of rest or by the use of another set of muscles.

E. The operator should be provided with aids to a maximum of comfort, consistent with restrictions imposed by the requirements of the process.
   1. Provide benches adjusted to a height which permits alternate standing and sitting.
   2. Provide chairs adjusted so as to permit good posture.
   3. Provide arm or elbow rests.
   4. Provide back rests for use during part of the work cycle, if the requirements of the operation do not permit sitting.
   5. Provide comfortable working temperature, proper humidity, good ventilation, adequate lighting, and freedom from noise and other distracting conditions.
   6. Provide platforms of wood, or mats made of a yielding substance, if the floor is made of concrete, metal, brick, or other hard materials.

[2]Not always necessary. Some people, especially negroes, can feel rhythm in almost any type of cycle.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Name one of the motion-economy objectives and one of the suggested means for putting it into effect.

2. State exactly how you would put the list of objectives to use in a concrete situation.

3. How can an overhead spring or counterweight for tools eliminate transport motions?

4. Give a few examples of combination tools. Under what conditions would such tools eliminate transport motions?

5. Why should as many as possible of the operations be performed in the same horizontal plane?

6. Give an example of using momentum to aid an operation.

7. "Transports should be as free as possible from pre-positioning motions." What are pre-positioning motions and how can they be avoided?

8. How can the elimination of the component "hold" promote safety?

9. In charting a bench operation, the analyst observes a delay component which could be avoided by making a few minor changes in bench layout. Should the component be considered avoidable or unavoidable?

10. How would you put rhythm into a seven-beat cycle? Why is rhythm important in routine operations?

Chapter 13

MATERIALS HANDLING AT THE WORKPLACE

After analyzing the work cycle and describing it in the form of a simo chart, it is necessary to examine each component in turn with the purpose in mind of reaching as many of the listed objectives as practicable. The means available for accomplishing these objectives can be classified into two broad categories: (1) those which involve plant layout and (2) those which involve motion economy. The first category has been considered in Part III. As for the second category, it is convenient to consider separately three subdivisions: (1) materials handling at the workplace, (2) jigs and fixtures, and (3) tools. Although it is desirable to study these three subdivisions separately, in order to avoid confusion, it is necessary in practice to bring them together and deal with them as one unit. In other words, not only should the materials-handling devices, the jigs and fixtures, and the tools be of the best possible design for the purpose for which they are to be used, but they must be arranged in the most desirable manner at the workplace, a factor which often results in the modification of initial designs.

The remaining chapters in Part IV are concerned with these matters of design and arrangement of devices which are used by the operator at his workplace. The purpose of the author is only that of introducing the reader to the conventional physical facilities and arrangements which are at the disposal of the analyst. Details of construction are outside the scope of this book, and such matters as are discussed will serve to orient the reader and provide a point of departure for him. The adroit analyst will have little trouble in devising facilities which embody the appropriate means of putting motion economy objectives into effect in specific situations. This phase of the

work of the analyst usually proves to be of the greatest interest, for it is here that he strikes out for himself into an unknown realm, and it is here that he puts the intangible "components," "objectives," and "means" into tangible form. Although each operation studied and completed by the analyst adds an increment to his store of practical knowledge and experience, it is rare, indeed, that an operation can be found in the plant or the office which duplicates exactly one which previously had been studied. It is this condition which keeps the analyst's work perennially fresh and interesting, and it is this factor which renders the compilation of an exhaustive check list of ways and means of accomplishing objectives, and the provision of all possible examples of physical aids to such accomplishment, a futile and hopeless task.

Drop Delivery Devices which Eliminate Unnecessary Transport Motions.—A fruitful source of savings involves the use of drop delivery conveying devices. These devices, of which there are many varieties, are used in delivering materials into position for use at the workplace, and in disposing of finished materials. The term usually refers to the use of gravity as the delivery force, though the impulse may be initiated by the aid of mechanical devices. It is considerably harder to utilize this principle in connection with the delivery of materials to the workplace than in the delivery of materials away from it. The following example of the former situation was adapted from a box-nailing machine. It was necessary to drive a nail into a block of wood, leaving 1/4" of the nail exposed. To eliminate the components TE, G, and TL, as applied both to hammer and nails, a nail delivery device was built which incorporated a foot operated hammer. A rectangular pan, which could be raised and lowered at one side, was placed above and in front of the operator. A slot in the bottom of the pan permitted the nails to drop through and hang in a row by their heads. Each nail was picked off in turn by a mechanism similar to the escape lever in a clock. As the nail was released it slid down a tube and was held in position over the block of wood. As the foot lever was kicked a metal rod came down the tube and drove the nail

the exact distance required. In this example the transport motions were entirely eliminated.

As for the elimination of transport motions in connection with the disposal of the finished product, much more practicable arrangements generally can be made. The sim-

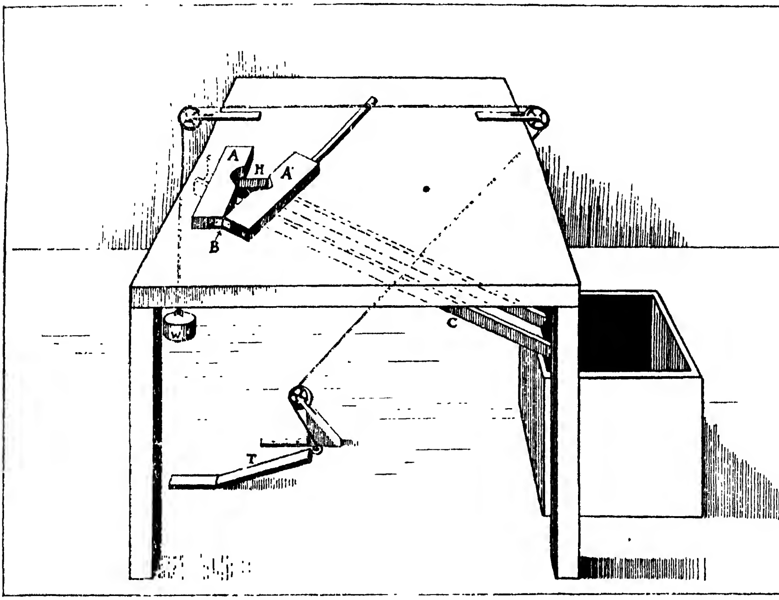


FIG. 27—*Simple arrangement for drop delivery. AA' indicate the jaws of a fixture. A is fixed and A' swings on hinge B. The part to be worked on is placed in the notches in the fixture and held in place by the weight W, which can be adjusted to give the required tension. When the operator has finished the process he presses the treadle T and releases the part which drops through the hole H and slides down the chute C into the tote box.*

plest involve fixtures (holding devices) which can be opened or rotated by pressure on a treadle, allowing the finished material to drop into a chute leading to a tote box. An example of a fixture which permits this type of drop delivery is shown in Figure 27.

ARRANGEMENTS WHICH PERMIT HANDLING MORE THAN ONE PART AT A TIME.—Special physical arrangements may

not be necessary in order to handle more than one part at a time, but the lack of such arrangements should not be permitted to block the savings which could result under conditions which make such a change feasible. If each hand can conveniently handle two or more parts at a time, without fumbling, a multiple fixture should be constructed. Simple assembly operations often can be carried out by such means. The assembly of two washers and a nut to a bolt is a case in point. If two bolts are placed upright in a fixture, each hand should conveniently be able to grasp simultaneously two washers and drop them onto the bolts. If the parts were of a size that permitted ease in handling, two bolts could be grasped in each hand and placed in a fixture, four washers could be conveyed to the fixture and two dropped successively onto each bolt by each hand, etc. Quite obviously, a point is soon reached where delays caused by fumbling will overbalance the advantages of eliminating part of the transport motions.

Mechanical Aids in Eliminating Transport Motions. —An almost infinite variety of mechanical means may be devised for moving materials into and out of position. Operators might, for instance, work on conveyors which move either continuously or intermittently. A movable circular table, a modification of this arrangement, often is used when the operations to be performed are few in number. A jet of compressed air, controlled by a foot pedal or automatically actuated, often is of help in propelling a part into or out of the fixture. This device is employed, for instance, in high speed punch-press operations for removing the punched blank from the die. If it is difficult to lift the finished part out of the jig or fixture, a mechanical ejector probably should be provided.

As one more possibility for reducing transport motions it is suggested that the work be arranged so as to increase the number of operations performed by one worker. This suggestion seems to run counter to the trend, which, in the past, has been toward greater subdivision of labor. The principle of subdividing operations can, however, be carried too far, and if the analyst discovers such operations he may be able to make savings by grouping operations.

For instance, the following operations, involving the assembly of paper cans, were being performed in three stages by as many different operators:

First operator—pick up base, brush glue inside, place base on bench near second operator.

Second operator—pick up glued base in one hand and neck in other, push neck into base, place assembled neck on bench near third operator.

Third operator—pick up assembled neck and base in one hand and top in the other, push top onto neck, drop assembled can into tote box.

Note in this example that there was a pick-up and a put-away motion before and after each of the three operations. One advantage which resulted from combining the operations was that the intermediate transport motions were eliminated.

ARRANGEMENTS WHICH PERMIT THE OPERATOR TO SLIDE PARTS INTO PLACE.—The ability to slide parts into place is of particular value when the materials handled are heavy or awkward to grasp and lift. It is better, for instance, to arrange conveyors which allow box-nailing machine operators to slide the packed boxes under the hammers than to force the operators to lift the packed boxes. When small parts must be assembled it often is possible to arrange the workplace so as to allow some of the parts to be slid into place. Fixtures which are sunk into the bench permit parts to drop into place. Such fixtures may consist of plastic materials which can be molded to fit the parts they must hold. If, however, the fixture must hold the part against pressure (as a nut into which a bolt is tightly screwed) the fixture should be made of metal.

Figures 28 and 29 show how sliding can be used to advantage.

Figure 28 shows how Mr. Hugh H. Boyes and Mr. Ray A. Wilson, Jr., of the Bendix Corporation, were able to substitute sliding for grasping and carrying parts to position. Two types of garlocks (pliable plastic washers) were used; both were convex on one side, but on the other side one was flat and the other was concave. These were slid from the trays to fixtures sunk in the bench, as shown in

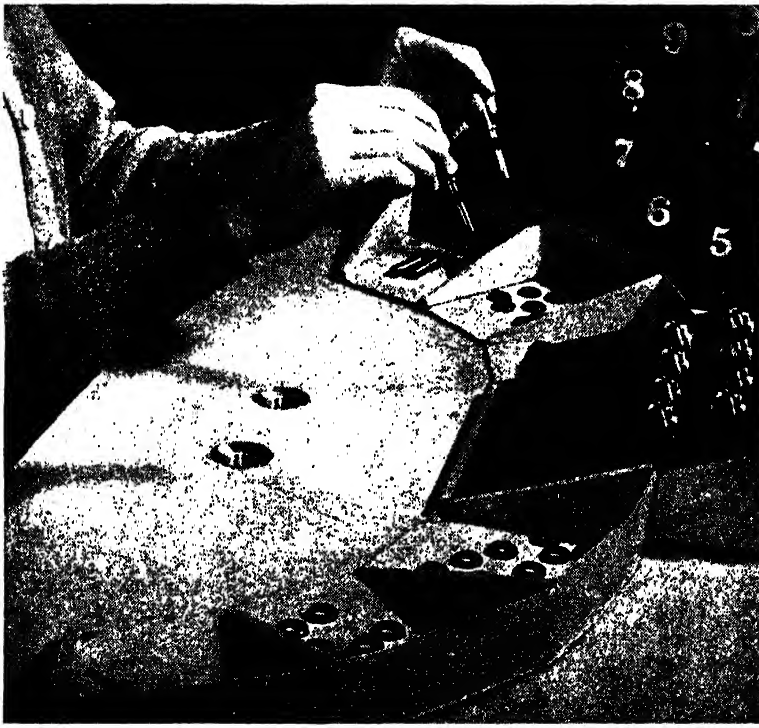


FIG. 28—*Arrangement which permits parts to be slid into fixtures. (Illustration by permission of Pacific Division, Bendix Aviation Corporation.)*

the illustration. Small cylinders then were forced down into the two sets of garlocks. The fingers retaining their grasp then lifted the assembled cylinders and garlocks out of the fixtures and set them in bases previously placed in a holder.

Figure 29 is a picture of a fixture which permits screws and keys to be slid into chutes which lead to small sacks. Originated by Mr. K. E. Greene and Mr. V. H. Smith, of the Norris Stamping and Manufacturing Company, Los Angeles, it solved the problem of how to reduce the time involved in sacking loose parts to be tied to assembled soap dispensers. A spring placed on the side of each spout held the sacks in place while the parts were slid from the semi-

cylindrical trays into the chutes. The bags were then detached and the drawstrings tightened in one motion, after which they were dropped into tote boxes.

USING MOMENTUM.—Heavy parts frequently come to the workplace down a conveyor from a higher level. A common mistake in bench layout involves an arrangement which

FIG. 29—*Arrangement which permits parts to be slid into sacks.*

prevents the operator from using the momentum generated by the part in its descent. The part is usually allowed to bump against a stop, or the momentum is dissipated in some other manner, after which the operator must overcome friction and inertia with his muscles by moving the stationary object into place. If heavy objects must be lifted from truck to bench, the truck should be so placed as to allow the worker to swing the object into place with one continuous motion. The skilled carpenter drives a nail in one or two long easy strokes which utilize the momentum of the metal head of the hammer. The novice expends much more muscular energy by using short, fatiguing strokes, to accomplish the same results.

PRE-POSITIONING BY VENDOR OR LOWER PRICED HELPERS.—If the time consumed in arranging the required parts in position for use is appreciable, the possibility should be investigated of buying the parts from a vendor who can supply them positioned properly in convenient packages. If the parts cannot be purchased in this manner, the job might be re-engineered so as to permit a lower-priced helper to place the parts on the bench in positions convenient for the operator.

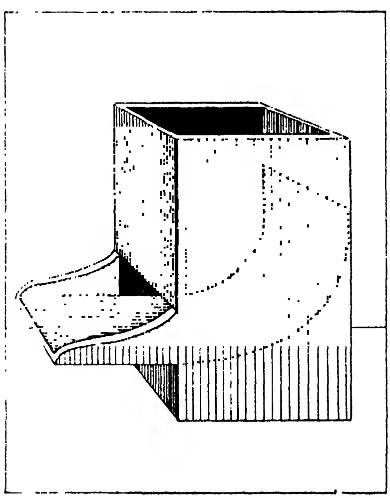


FIG. 30—*Type of bin which facilitates the grasping of small parts.*

ARRANGEMENTS WHICH FACILITATE GRASPING.—The analyst often is confronted with the problem of eliminating fumbling and facilitating the grasping of small parts. An arrangement which is satisfactory in most cases is a bin equipped with a tray which allows the operator to select and grasp easily. (See Figure 30.) A pressure or friction grasp is the kind used in picking up an object from a flat surface. The difficulties involved in employing such a method are apparent when one attempts to pick up a small coin, washer, or nut from a flat, hard surface. But if the part can be slid to the edge of the table so as to allow the finger to encircle it, the component grasp can be greatly shortened. A hook grasp often results if the parts are placed upon felt or sponge rubber pads.

POSITIONING AIDS.—Most of us are familiar with the devices on a typewriter which reduce positioning delays to a minimum. A movable backstop guides the paper easily under the platen and an adjustable guide on the left side of the backstop enables the typist to put each sheet in the correct position. The carriage strikes an adjustable stop at one end and a bell at the other, and a ratchet arrangement enables the typist to space the lines evenly.

Repetitive operations which require positioning can be accelerated by the use of adjustable guides and stops. In punch-press operations the sheet metal is slid along a guide until it strikes a pin. If the machine is tripped while the sheet metal is in this position the die will stamp out the blank correctly. With such arrangements, positioning time is reduced to a minimum; as a matter of fact the operator hardly realizes he is doing any positioning, the operation is so easy.

If parts are to be slid into a fixture sunk into the bench, the use of grooves or other types of guides will facilitate the operation.

CALCULATING THE NUMBER OF UNITS BY WEIGHING.—It is often necessary to know how many small parts have been produced. If the parts are uniform in weight the number in a lot can readily be calculated from the total weight. If balance scales are used, the weights can be set in such manner that one part in the pan at the end of the balance arm

equals 100 (or some other large figure) in the tote box on the platform. Thus the checker needs only count parts into the pan until the scales balance, then by mentally multiplying the number in the pan by 100 he obtains a close estimate of the number in the tote box.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What is meant by "drop delivery"? Give an illustration.
2. Why is it so much harder to develop drop delivery devices for conveying materials to the work place than for disposing of finished units?
3. Explain the use of multiple fixtures for handling two or more parts at once. Will not the use of such fixtures cause fumbling on the part of the operator?
4. Give an example of a device or arrangement which serves to eliminate transport motions.
5. It is desired to slide washers and nuts into place in connection with their assembly to bolts. What physical arrangements must first be made at the work place?
6. Give an example in which momentum is used to aid the operator.
7. Give an example in which momentum neither aids nor hinders the operator, but is dissipated in some manner.
8. Give an example in which momentum hinders the operator by necessitating unnecessary muscular effort.
9. How do you account for the fact that it often is possible to obtain parts in "pre-positioned" packets at little or no extra cost?
10. Differentiate between a pressure or friction grasp and a hook grasp, and indicate what mechanical arrangements will enable the operator to use a hook grasp.
11. How does the tabulating key on a typewriter operate? How can this principle be used to reduce the positioning component in industrial operations?

Chapter 14

POSITIONING AND HOLDING DEVICES

As a rule, the analyst realizes his greatest savings by reducing or eliminating the components "position" and "hold." In order to do this, positioning and holding devices are used. These devices are known as jigs and fixtures. In practice, jigs or fixtures are devices which hold parts while holes are being drilled in them, while they are being machined, or while they are being assembled or otherwise processed, and which assist, at the same time, in positioning tools or other parts. Individually, the terms are often used interchangeably. Correct usage, however, seems to place the emphasis on positioning in jigs and holding in fixtures. Usually the jig is not fastened to the machine on which it is used. Its primary purpose is that of guiding drills and other tools to the exact spot on the material in a minimum of time. Fixtures, on the other hand, primarily are convenient holding devices. When they are used on a machine they are fastened to it and the tool is moved to the material, or, in the case of the milling machine, the table, with the fixture attached, is moved to the cutting tool. Templates are simple jigs, and vises, angles, and V blocks are simple fixtures.

It is the purpose of the writer to indicate only in the briefest manner how jigs and fixtures are of use in attaining the objectives of motion economy. The student should, however, inform himself further concerning these aids, and for that purpose he is referred to *Jigs and Fixtures,* a reference book showing many types of jigs and fixtures in actual use, and suggestions for various cases, by Fred H. Colvin and Lucian L. Haas, and Chapter IX of *The New*

Encyclopedia of Machine Shop Practice, written by J. S. Murphy and edited by George W. Barnwell.[1]

DEVICES WHICH ELIMINATE THE COMPONENT "HOLD."—According to the Taft-Peirce Manufacturing Co.,[2] the following factors should be considered when designing a fixture: (1) the fixture should be as simple as possible, (2) the clamping device should be rigid, (3) the fixture should be so designed as to permit the correct sequence of operations, (4) there should be no interference with the tool, (5) there should be no interference with the machine on which it is used, (6) adequate clearances should be left for the work and hands, (7) chip pockets should be avoided, (8) locating points should correspond with dimensions on the part drawing and with locating points on other tools for the same part, (9) the fixture should permit convenience and speed in operation, (10) it should be possible to do accurate work while using the fixture, (11) the fixture should be durable, and (12) fabrication costs of the fixture should be economical.

In the design of fixtures it is necessary to know (1) what is to be held, (2) what is to be done with the part being held, and (3) how the operator expects to accomplish the operation. If two or more successive operations necessitate placing the part in different positions, a swivel fixture may allow rapid positioning without taking the part out of the fixture for each operation. Attention should be paid to the paths followed by the hands of the operator. The fixture should be constructed and located so as to permit direct and positive motions. Roundabout motions should not be required. Neither should awkward turning and "pre-positioning" motions be required by the hands while loading or unloading the fixture.

JIGS.—The most common form of jig is the box type. The part is placed in a rigidly welded metal box, the lid is closed and clamped, and the bushings, located at the proper places in the box, permit drilling to be done quickly and accurately. Although such jigs must often be used, it is better to use

[1]Published by McGraw-Hill Publishing Co., New York (1938), and Wm. H. Wise, New York (1941), respectively.

[2]Colvin and Haas, *Jigs and Fixtures*, p. 13.

simpler types, if possible. The box type cannot be used rapidly. It is hard to load and unload, and it is somewhat troublesome to keep clean. Often guides for the material and quick-acting clamps to hold it in place are sufficient to accurately position tools. A variety of such clamps and devices are described in Chapter IX of Barnwell's *New Encyclopedia*. Such clamps should always be used for fixtures as well as jigs. It often is possible to use foot treadles to operate clamping devices. Frequently the mistake is made of constructing foot-operated clamps so as to necessitate the holding of the part by resting the weight of the operator on the treadle. It is less fatiguing if the clamp is made to hold the part by means of a spring or counterweight, reserving foot pressure for opening the clamp.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. How can the component "hold" be eliminated?
2. How can the component "position" be reduced?
3. What is a possible difference between jigs and fixtures?
4. Name as many factors as you can which should be considered when designing a fixture.
5. It is necessary to attach parts both to the top and bottom of a small machine part. How can the assembly be performed without removing the part from the fixture and turning it over? Answer specifically.

Chapter 15

TOOLS

Effective motion economy requires the use of many forms of special tools and tool mountings, or tool holders. It is the purpose of this chapter to present a few examples of

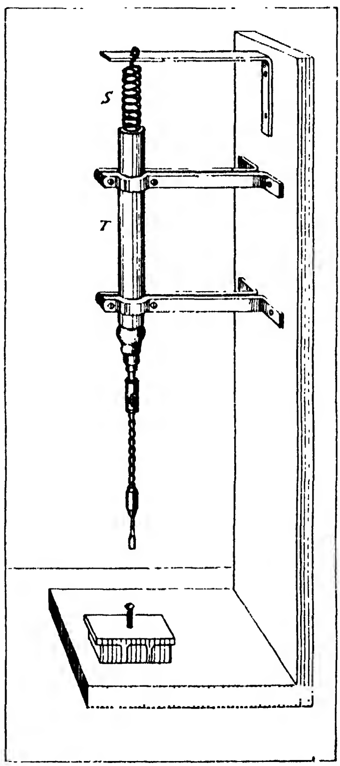


FIG. 31—*Spring suspension for spiral screwdriver.*

tools and holders which have proved in practice to be useful.

OVERHEAD SUSPENSION OF TOOLS.—The term "drop delivery" is sometimes applied to overhead spring or counterweight suspension of tools. The suspension of a spiral screwdriver, as shown in Figure 31, eliminates TL and TE after the screwdriver has been used; it is only necessary to release the handle, and the screwdriver automatically springs up into place.

Another type of suspension, developed by Professor David Porter, eliminates the need to position the screwdriver or wrench, inasmuch as it operates on a frame which does not permit sidewise motion. See Figure 32.

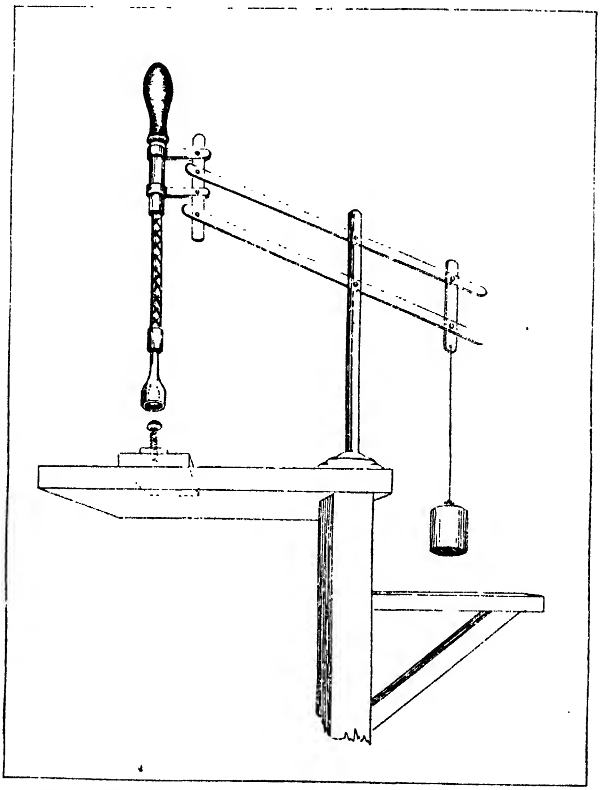


FIG. 32—*"Pantograph" mounting for spiral screwdriver.*

Counterweight suspension of tools is also used to reduce fatigue when heavy tools must be lifted. Impetus was given to such arrangements at the start of the war, when so many women were taken into industry.

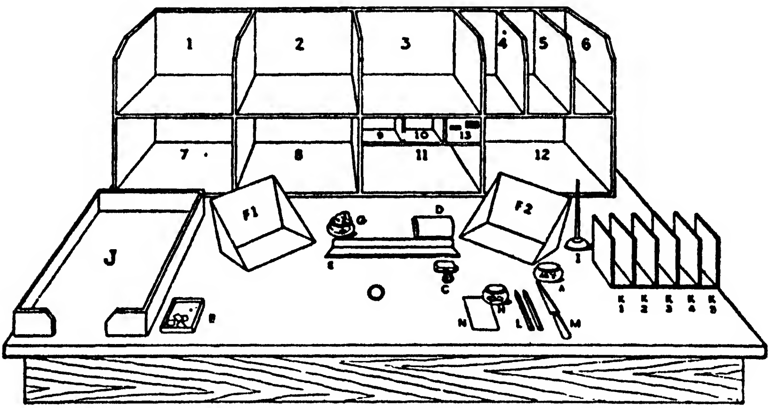
Although the ratchet screwdriver or wrench is handy, it is much better to use power-driven tools wherever possible. A power-driven wrench, for example, equipped with a clutch which permits the wrench to slip when the nut or bolt has reached the desired tightness, mounted on a frame provided with a counterweight, provides a very effective aid in assembling parts.

COMBINATION TOOLS.—The use of combination tools eliminates transport motions and substitutes an end-for-end motion or a twisting motion. For instance, a pencil with an eraser on one end is a combination tool. With such a tool it is not necessary to lay the pencil down, reach for an eraser, put the eraser aside, and pick up the pencil again. By simply turning the pencil end for end, the following motions are eliminated: TL (pencil), R (pencil), TE (to eraser), G (eraser), TL (eraser to paper), TL (eraser aside), R (eraser), TE (to pencil), G (pencil), and TL (pencil to paper). The motions actually involved are, of course, a short TLP (bringing the eraser to the paper), M (using the eraser), and another short TLP (bringing the pencil to the paper). Some positioning (P) might also be necessary in both cases. Other examples of combination tools would include two-ended wrenches, claw hammers, certain dental instruments, and a host of special tools used in industry.

AIDS TO ASSEMBLING IN INACCESSIBLE PLACES.—As aids in assembling small parts, it is suggested that tools be used employing magnetism, friction, adhesives, or suction. The magnetic screwdriver and tackhammer are familiar tools which aid in handling small parts which are difficult or, often, impossible to manipulate without such help. Friction is called into play, for instance, when a nut which cannot be started by hand is forced into a tightly fitting socket wrench, after which the wrench can be placed where the hands will not fit. If the wrench does not permit the nut to remain in place by means of friction, a commonly used

adhesive, grease, probably can be used to advantage. Difficult cases of assembly in inaccessible places often can be solved, also, by the use of suction cups of various kinds.

INSTRUCTION SHEETS.—Although the workers have been properly trained in the principles of motion economy, it is necessary to prepare clear directions for the performance of new operations. Workers should be encouraged to sug-



Courtesy of Aldens Chicago Mail Order Company

FIG. 33—*Bench layout for mail opening and jacketing operations.*

LAYOUT OF DESK EQUIPMENT

A Pin Bowl
B Ration Stamps
C Stamper
D Ink Pad
E Folded Jackets
F 1 and 2 Unopened Mail
G Sponge
H Coins
I Spindle
J Book Orders
K Remittance Classification Rack
  1 Dollar Bills (any denomination)
  2 Postal Money Orders
  3 Express Money Orders and Competitor's Refunds which have the name of a New York or Chicago bank printed on them
  4 CMO and other acceptable Refunds
  5 Competitors' Refunds which have no bank name printed on them
L Pencils (black and green)
M Letter opener
N Stamp Envelope
O Work Area
  1 No Cash
  2 Singles
  3 Personal Checks
  4 Coin and Stamp Envelopes (F 1564 Rev.)
  5 Jackets
  6 Brown Envelopes
  7 Time Payment and COD Remittances
  8 OK's
  9 Sample Envelopes (E-1588)
  10 Stickers
  11 Due Us
  12 Ration Books
     Non-acceptable Ration Stamps
     Mail Not for Us
     Other
       Miscellaneous
  13 Ration Stamp Identification Card

gest improvements in their jobs, but they should not be expected to design bench layouts and work out detailed directions for the jobs. Customarily, instruction sheets are furnished to the operator with each new job. At the outset, considerable time is required by the operator to read and absorb the instructions. This time is considered by the analyst as planning, a form of unavoidable delay. The delay involved in reading directions and in recalling directions previously read can become serious if jobs change often and if the labor turnover is high. To reduce such delay, it has been deemed expedient to dispense with the traditional blueprint and to substitute in its place perspective drawings or photographs showing the successive steps to be taken. Often, the parts themselves can be wired to a board so as to show clearly what is to be done. The method to be employed in performing the operation—the bench layout and the sequence of operations—is shown by means of diagrams, or pictures, and by detailed written instructions. An example of a clearly written instruction sheet is shown below. It was written by Mrs. Ralph W. Higbie for the Aldens Chicago Mail Order Company.

Routine Steps of Mail Opening-Jacketing

Preparation

1. Take a pile of about 100 jackets and fold them all at once, so that the entire colored band is visible on top. Use your letter opener inside the fold and press down with your left hand on top.
2. Place folded jackets against metal strip at rear of Area O.
3. Take one stamp envelope (F 1564 Rev.) from Pigeonhole 4 and place at right of Area O, with flap extended. Either side may be up, depending on which side has room for stamp entries.
4. Place initial rubber finger on right index finger.
5. When you receive your signout of overweight or odd size mail, use your letter opener to slit *bottom* edge of envelopes. Just spread the pile slightly, and slit envelopes one right after the other. Place in regular letter bins,

using care not to spill loose coins. Open from there on, just like regular slit mail.

Following is the step by step procedure for most efficient Mail Opening and Jacketing. When a step in the column marked "Right Hand" appears directly opposite a step in the column marked "Left Hand," perform both steps at the same time.

1. Bearing in mind whether disposal area for previously handled order was on right or left half of desk, choose your instructions.	a. If disposal area was on right half of desk, follow instructions 1A and 2A. b. If disposal area was on left half of desk, follow instructions 1B, 2B, and 3B.
Left Hand	*Right Hand*
1A. Place fingers on top and thumb inside envelope, on top of contents. Area F1	Dispose of finished order.
2A. Bring envelope to center of desk.	Insert fingers and thumb in envelope, on top of contents.
OR	
1B. Dispose of finished order	Place fingers on top and thumb inside of envelope, on top of contents. Area F2.
2B.	Bring envelope to center of desk.
3B. Insert left thumb in envelope, on top of contents.	Insert fingers and thumb in envelope, on top of contents.
4. Tear left side of envelope.	Tear right side of envelope, by pressing down with thumb, and up and out with fingers. Hook fingers underneath contents.
5. Flip underneath side of envelope out, and place flattened envelope on jacket.	Be sure that the far edge lies along the inside of the jacket fold, and the left edge along the left edge of the jacket.

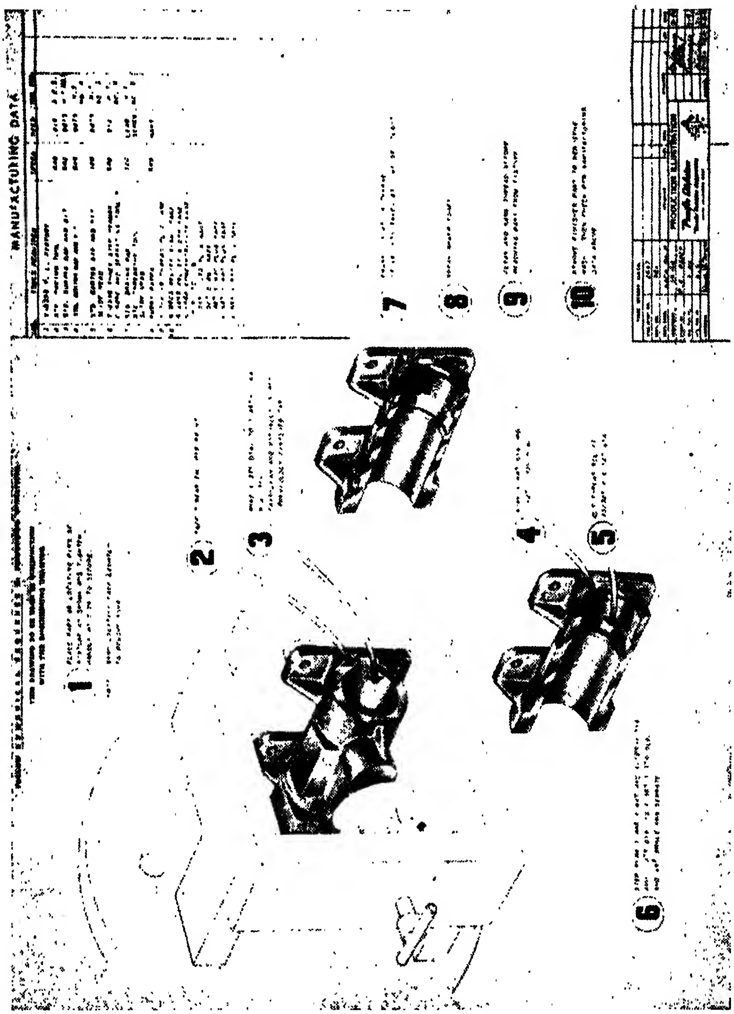


FIG. 34—*Production illustration.*

INSTRUCTION SHEETS WHICH INCLUDE PERSPECTIVE DRAWINGS.—Bendix Aviation Corporation uses clearly designed instruction sheets, one of which is shown in Figure 34.[1] It states that numerical sequence should be followed in performing operations, and directions to the operator are given opposite each large encircled number. Arrows point to the exact point which is to be processed, so there can be no misunderstanding. The directions often refer the operator to a table of manufacturing data (shown in the upper right-hand corner) or to an attached engineering drawing (not shown in this example).

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What tools can be suspended overhead to advantage?
2. What is the chief advantage of the "pantograph" form of tool suspension?
3. Name as many combination tools as you can.
4. To what hand tools can electric power be applied to advantage?
5. What, in your opinion, should be included in effective instruction sheets?

[1]Furnished through the courtesy of Mr. Hugh H. Boyes, Supervisor, Time Study and Standards Department, Pacific Division, Bendix Aviation Corporation.

Chapter 16

BENCH LAYOUT

Many of the objectives of motion study can be attained by proper layout of the workplace. It is the purpose of this chapter to present a few specific illustrations of layouts which have enabled their originators to reduce fatigue and increase accomplishment.

ENDING A CYCLE AND STARTING A NEW ONE WITH A CONTINUOUS MOTION.—Several objectives have been attained in the layout shown in Figure 35. One involves putting aside a finished assembly and starting a new cycle in one continuous motion. The operator is shown sliding two parts from the inside trays to the fixtures. This motion constitutes the beginning of a new cycle. The previous cycle ended with the placing of two assemblies in the holder between the two inside trays. The hands then continued moving toward the inside trays. One round trip thus sufficed to dispose of the finished product and deliver the first parts into position in the fixtures.

REDUCING UNNECESSARY REACHING.—If excessive reaching is to be avoided during the work cycle, it is necessary to locate materials, tools, and controls within the normal and maximum work regions of each hand. These regions can be found for each individual by having him sweep the space over the bench with each arm, first with elbows at the sides and then with arms fully extended. The region or space covered most naturally by the operator, without bending, stretching, or changing posture, is the region in which as much of the work as possible should be done.

REDUCING THE DISTANCE TRAVELED BY THE HANDS.—Bench layouts frequently can be improved by diagraming each hand through one cycle and then by trying to shorten the distance traveled. Care should be taken not to restrict

the distance traveled to the point where motions become constricted and unnatural.

ARRANGEMENTS WHICH PERMIT THE HANDS TO WORK IN THE SAME HORIZONTAL PLANE.—Working against gravity should be avoided as much as possible. To that end materials, tools, and controls should be located as near to the same horizontal plane as possible. The layout shown in Figure 36 illustrates this objective. The nature of the assembly was such that the fixture had to be raised from the level of the bench top. Had the parts been fed to the operator at bench level, it would have required repeated raising

FIG. 35—*Correct bench layout for a product which cannot be dropped after assembling. (Designed and constructed by Hugh H. Boyes and Ray A. Wilson, Jr. Illustration by permission of Pacific Division, Bendix Aviation Corporation.)*

and lowering of the hands to perform the necessary operations. By raising the chutes which fed the parts to the operator, the hands were enabled to work continuously in one horizontal plane.

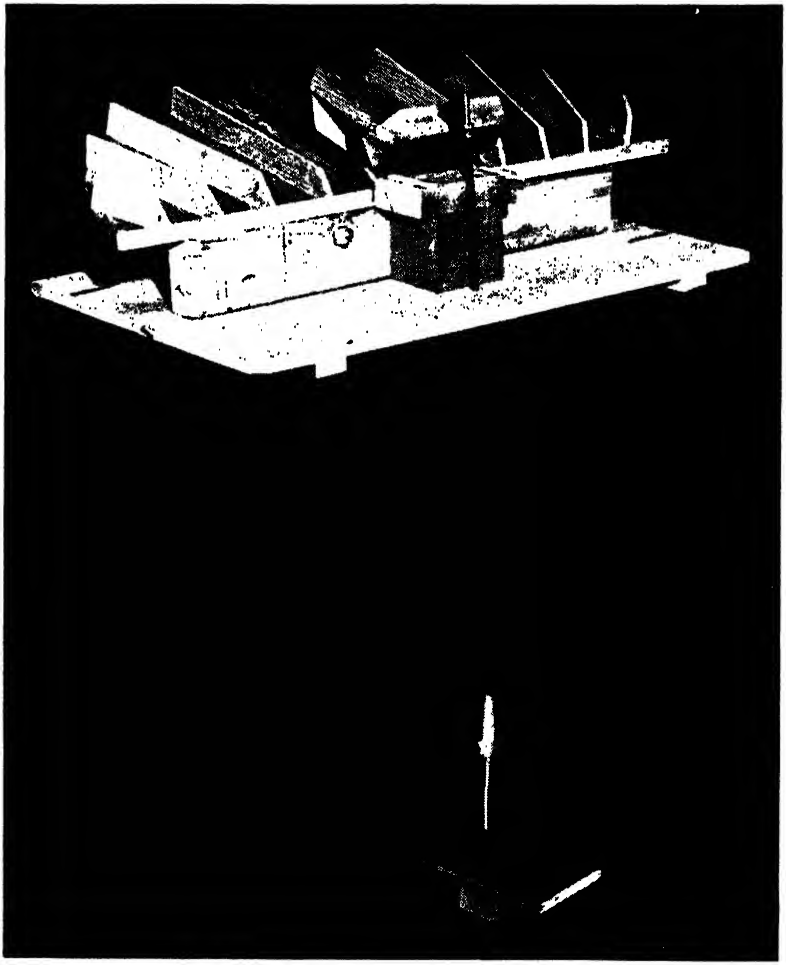


FIG. 36—*Bench layout which permits the hands to work in one horizontal plane. (Designed and constructed by Miss Jude Christopher and Mrs. Joy Cochran.)*

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Describe the normal and maximum work regions of the hands.
2. Where should tools and materials be located with reference to the normal and maximum work regions?
3. Why is it important that tools, controls, fixtures, and materials should be located as nearly as possible in one horizontal plane?
4. In reducing the distance traveled by the hands, what precaution should be taken?
5. Give an example of an operation which, if performed with a first degree motion, would result in greater fatigue than if performed with a third degree motion.

PART V

TIME STUDY

Chapter 17

OBSERVING AND ANALYZING THE OPERATION

In Part V we are interested in determining standard periods of time for performing work. Inasmuch as setting time standards must follow detailed job description, it is essential that the observer be able to describe in written words and sketches what he sees. Furthermore, it is essential that the observer have the ability to analyze jobs into their elements and properly classify them. Observation and analysis go hand in hand, and comprise the first stage in time study. Reading the stop watch and recording times constitute the second stage. The exercise of judgment in rating the operator and in making allowances is the third stage. And calculating the standard is the fourth, and final, stage. There are other activities connected with time study, but they are considered either as sub-heads in the above classification, or as activities exercised in common with motion study.

EQUIPMENT OF THE OBSERVER.—The observer uses certain equipment to aid in establishing time standards. It should be understood at the outset, however, that good equipment does not make a good observer. The writer has often heard the expression: "That standard appears to have been made with an alarm clock!" The mental attitude indicated by this expression is wrong. A good observer can set a better standard with an alarm clock, a pencil, and a scratch pad than a poor observer can establish with first-class, complete equipment. Equipment no more makes the observer than clothes makes the man—but it helps.

THE WATCH.—Although some individuals have such a well-developed sense of rhythm they can estimate time pe-

riods with a high degree of accuracy, the rest of us require a timing device. It is not the purpose of the author to enter into a detailed discussion of the merits and demerits of the various types of watches that can be used. Such discussion is fruitless unless one knows the conditions under which the watch is to be used. If standards are to be established in terms of hours per 100 units, the decimal hour watch is convenient. The practice in some plants, however, is to set standards in terms of minutes per unit, under which conditions the decimal minute watch would be preferred. (See Figure 37.) Although decimal watches are

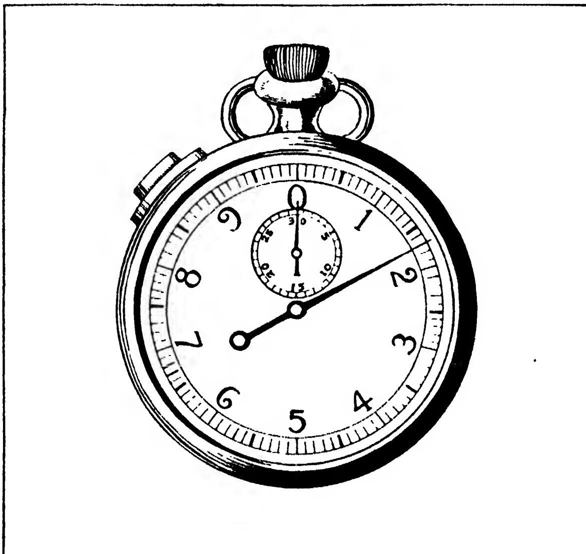


FIG. 37—*Decimal minute stop watch.*

preferred, they are not essential, for seconds can easily be converted to minutes, and minutes to hours. Computations are, of course, always easier in terms of decimals than in terms of fractions.

Various watches are available which are used for timing contestants in races. Although such watches *can* be used in time study, they are not desirable. In the first place,

they usually are calibrated to time in seconds, and, in the second place, they are mechanically awkward to handle. In the shop it is desirable not only to measure short periods of time but long periods, as well. Furthermore, it is often desirable to stop the watch, then to proceed from the same

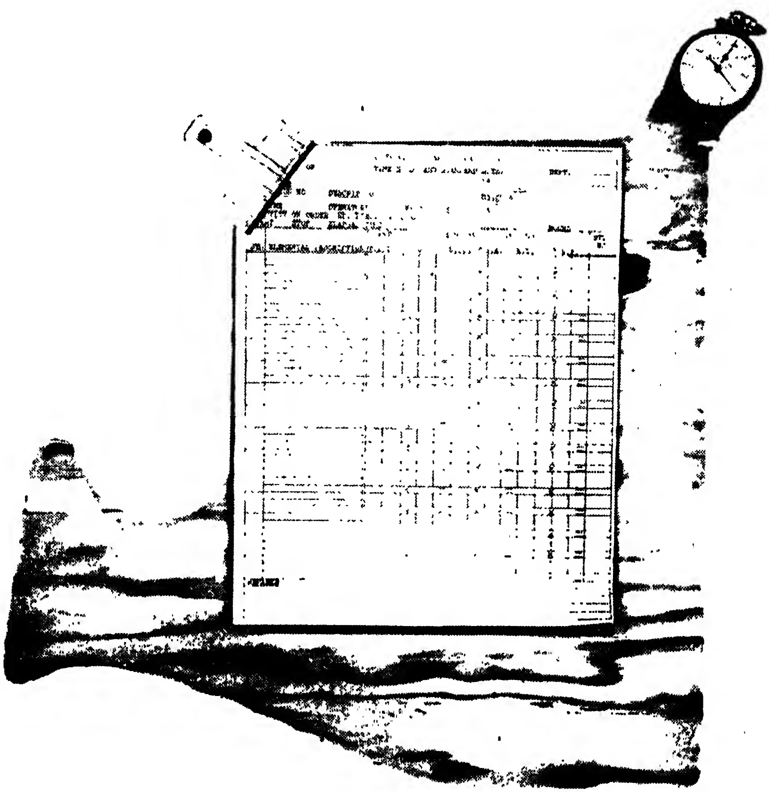


FIG. 38—*Observer's time study board.*

point. It is for the latter reason that pocket watches are inconvenient. The best mechanical arrangement in a stop watch is that which (1) permits the observer to snap the hands back to zero by depressing the stem, (2) allows the observer to begin timing again almost instantly by releasing the pressure on the stem, and (3) allows the observer to "cut" time out by means of a slide, which, when moved counter-clockwise, freezes the hands of the watch and which, when moved back again, allows the hands to continue.

THE OBSERVATION BOARD.—A board, to which are attached paper and the watch, is almost essential. The observer must be free to move about, so he cannot write on a desk while recording observed times. Although the watch can be held in the hand while the board rests on the arm, it is a convenience to attach the watch to the board where it can be read and manipulated easily. Boards of various sizes and shapes are used by observers. The board shown in Figure 38, a handy size and shape, was used by Mr. Robert Boos at the Santa Monica plant of Douglas Aircraft Company, Inc.

THE TIME STUDY SHEET.—There are almost as many forms, on which observations are recorded, as there are plants. The form must reflect the needs of the local department. It is useful in three ways: it reminds the observer to secure all essential information, it encourages uniformity, and it classifies the data into neat sections. It should provide space for identification and description of the job, necessary sketches, identification of the observer and the operator, date of the study, observed watch readings, speed rates, allowances, and any other information which the department finds useful. As a rule, standards are calculated on this form, and the methods of arriving at the answers are shown. A headsheet may be provided, to which these worksheets are attached, and on which descriptions, element times, and the job standard are shown. The name of the department in which the study was made, and the code number of the standard should also be shown on the headsheet, to facilitate filing. The data on the headsheets are frequently typed, with carbon copies for the superintendent's office, the foreman, the cost accounting

office, and the planning department. Some plants may require space on the headsheet for the signatures of the standards department head, the plant superintendent, and the union representative.

OTHER NECESSARY EQUIPMENT.—It is hard to see how a time-study observer can do effective work without a slide rule. Even though his standards are calculated for him, his work is of such nature that he needs this aid to rapid estimating almost every hour of the day.

A mechanical counter is frequently of use, especially in timing many extremely short intervals. The counter raises the number shown on the face by one each time a lever is depressed, and it can be turned back to zero. An example of its use is the timing of an automatic punch press. If the time for 100 strokes is desired, the watch is snapped to zero at the beginning of the first stroke; at the end of the first stroke, and for each succeeding stroke, the counter lever is pressed; and as the 100th stroke is counted the watch is stopped. Even though the strokes are slow enough to count mentally, it is easier and the chances of error are less when a counter is used.

Occasionally speed indicators for revolving wheels and shafting will be found useful. A flexible rule for measuring short distances is, likewise, useful, and, of course, a pencil is indispensable.

PREPARING FOR THE STUDY.—The assignments which may be given to an observer are almost infinite in variety. Consequently, it is difficult to be specific when discussing how to prepare for a time study. In general, however, the observer should obtain as much information about the job as he can get from the files, from the specifications, and elsewhere in the office. If the job has been studied previously, he should read the description. If the job has not been studied previously, he should read descriptions of similar jobs. He should be told the purpose for which the study is to be made. If possible, he should know the operator he is to observe before he goes into the plant. He should be acquainted with the operator's production record and whether he is skilled, semi-skilled, or unskilled. It helps if the observer knows, also, something about the personal-

ity of the worker he has selected to time. This phase of the time study might be likened to that phase of a sale which the salesman calls the "pre-approach." Anything about the job and about the operator or operators which the observer can learn before he approaches the vicinity of the job will help to make his task easier.

APPROACH TO THE DEPARTMENT.—The next step to be taken by the observer depends upon a great many factors. If he is entering a department which has never before seen a time-study observer, it is highly desirable that the workers be prepared. It is assumed that an observer will never be sent into a department without proper introduction of the program and the observer to the foreman. The attitude of the foreman usually determines the attitude of the workers of his department. If the foreman is antagonistic toward the observer, the workers will not cooperate in the establishing of standards. If the foreman treats the observer as though he did not exist, the workers will evince considerable curiosity, but will neither help nor hinder—a situation which is far better, incidentally, than one of hostility. If the foreman is friendly, half the battle is won. Sometimes, if the foreman is not a real leader, he takes his cue from his men, and a situation exists which is the reverse of that described above. Under such circumstances the program should be explained to the leaders among the employees.

Normally, the observer will report to the foreman upon entering the department. The foreman should have been notified previously. (The writer has worked in plants in which the foremen initiated requests for time studies.) The foreman or his representative should take the observer to the job and explain anything about it the observer does not understand. The matter of whom to observe, among those eligible, is one to be settled mutually between foreman and observer. And since the foreman is a line officer and the observer only a staff officer, without the power to give orders to the workers, the foreman should delegate such power for the purposes of making a time study and, furthermore, such delegation of authority should be made in the hearing of the workers concerned. This is the only fair way to han-

dle the initial entry of the time-study observer into a department. It is based upon modern concepts of management. Everyone in the organization should look to one person, only, for orders. The one person in each sub-division of the organization who has the power to issue orders and compel their performance is the line official. Staff employees act in an advisory capacity only and thus cannot issue and compel obedience to orders. But since time-study observers (staff employees) are responsible for getting time studies in the plant and office and since it is a principle of good management to make responsibility and authority coextensive and conterminous for each person in the organization, it logically follows that someone must give the observer enough authority to fill out the limits of his responsibility. Since it would be impracticable in practice for the observer to ask his boss, the head of the standards department to ask the general manager to order the superintendent to order the foreman to delegate authority to the observer, the foreman should do this without being told. Furthermore, any foreman who values his prestige would not permit an "outsider" to come into his department and issue orders to his employees without first obtaining and being granted his permission. And, last, no observer who knew anything about the etiquette of business would "barge" into another man's jurisdiction and start making suggestions to people to whom it is that man's exclusive prerogative to make such suggestions.

Considerable space has been given to the approach of the observer to the foreman for the reason that time-study observers are never too popular, and a self-important, pompous attitude in which the proprieties are ignored in an effort to impress his importance upon everyone concerned cannot help the observer's chances among workers and foremen.

The discussion to this point deals with beginnings. If the observer has been in the department previously, the foreman might give him *carte blanche* to observe any and all operations in his department, but the observer should never presume to impose upon the foreman for this courtesy.

The difficulty of trying to outline the observer's approach can be appreciated when it is understood that there are all kinds of foremen. The writer has often found a good-natured negative, or "kidding," approach of value. The observer who can successfully use such an approach to the foreman, need not worry about his relations with the workers.

APPROACH TO THE WORKER.—All workers should be acquainted with the aims and purposes of the standards department. This information can be conveyed by means of vestibule schools, printed booklets giving general information about the concern, the union representatives, special meetings, conferences, motion pictures or slides, etc. It should not be necessary for the observer to repeat fundamental information about the program to each new employee he observes. He should, however, tell the worker why he is timing the job, and he should answer the worker's questions fully and courteously. Workers are always curious about the stop watch, and their curiosity should be satisfied. There is no harm in allowing a worker to manipulate the watch controls and in letting him see the times as they are recorded. It is not necessary to explain rating unless it is evident that such an explanation would be helpful. The writer once made such an explanation to a girl who had had a quarrel with the neighboring girl who was being timed. The first girl confidentially revealed that the other girl was slowing down while being timed. When she was told that it made no difference in the standard; that all performances were rated and that the times were adjusted upward or downward depending on whether the operator worked rapidly or slowly, her surprise was great and her unconsciously admiring comment was: "You're not as dumb as you look!"

The observer should tell the operator the purpose of his visit to the plant and he should not hesitate to ask the operator for necessary information. If several workers are performing identical operations, it is a good plan to time each of them for a few cycles, provided the cycles are short and there are not many available workers. This practice tends to eliminate much of the embarrassment and jealousy

which often results when only one worker is selected, and it still is possible to spend more time observing the person who gives the most satisfactory performance. This practice also allows the observer to obtain more than one set of data which can be used for checking purposes. If the workers are not thoroughly sold on the idea of time study, this procedure is likely to cause the workers to think the observer is trying to find the fastest worker, so it should be used with caution.

It is considered good practice to ask the permission of the operator before timing him. As a matter of fact, a good personnel policy would insist that this courtesy be shown to the workers. The reason is not hard to see. Large corporations are increasingly trying to find ways of keeping the morale of their workers high. Nothing destroys the morale of an organization quite so quickly and completely as to follow lines of action which tend to humiliate the individuals which comprise it. Contrariwise, action which tends to foster the self-esteem of the individuals which constitute an organization will do much to raise the morale of the group.

ANALYZING THE OPERATION.—Before the observer begins timing the operation he must know exactly what to time. He must know what comprises the work cycle, and on what unit of production the standard is to be based. In Chapter 11 we learned that a work cycle consists of all of the operations necessary to complete a given job for a given number of units. We know, also, that we cannot determine the cycle until we have specified the unit and defined the job. Inasmuch as the proper analysis of an operation frequently proves to be a stumbling-block in the path of the observer it is well to exercise considerable care at this point.

THE STANDARD UNIT.—Once the unit has been determined it should be kept clearly in mind. All observed times must be expressed in terms of that unit. For instance, if the unit is "1 box," all work done in connection with the job, as subsequently defined, must be expressed in terms of 1 box. If packing is one of the elements of the job, the time should be expressed in terms of decimal minutes or hours per box. If the job includes wrapping the articles which

are to be packed in the box, it is clear that the time should not be expressed in terms of decimal minutes or hours per article wrapped but rather in terms of time per box. It is essential, in this case, to know how many articles are to be packed in each box. Although most observers will *not add* "hours per box" to "hours per article wrapped," the writer has caught experienced observers adding "hours per bolt" to "hours per assembly" in order to obtain a standard! Another example will make this clear. A worker assembles two bolts and nuts to a casting with two holes drilled through it. The job is described briefly as follows:

A—Get casting from tote box #1.
B—Get bolts from tote box #2.
C—Get nuts from tote box #3.
D—Assemble two bolts and nuts to one casting.
E—Carry assemblies to storeroom.

Most beginners become engrossed in the intricacies of timing and set up a standard somewhat as follows:

The worker carried 10 castings to the bench in 0.4 minutes. The time for Element A is, therefore,

$$0.4 \div 10 = 0.04 \text{ minutes}$$

The worker carried 100 bolts to the bench in 0.5 minutes. Likewise, the time for Element B is,

$$0.5 \div 100 = .005 \text{ minutes}$$

Five hundred nuts were carried to the bench in 0.5 minutes. Element C is,

$$0.5 \div 500 = .001 \text{ minutes}$$

Ten assemblies were made in 1 minute. The next element is,

$$1.0 \div 10 = 0.1 \text{ minutes}$$

Fifty assemblies were carried to the storeroom in 5 minutes. The last element is,

$$5 \div 50 = 0.1 \text{ minutes}$$

To tabulate the data:

Element A=0.040 minutes
Element B=0.005 minutes
Element C=0.001 minutes
Element D=0.100 minutes
Element E=0.100 minutes

No error has been made to this point, but the danger

of using this method is that the temptation to add these element times is so great that nearly all beginners will take the easy way out, and say that the standard should be 0.246 minutes per assembly. The fallacy, obviously, lies in the fact that Element A is expressed in minutes per casting, Element B in minutes per bolt, Element C in minutes per nut, and Elements D and E in minutes per assembly. It is no more possible to add these values and get "minutes per assembly" than it is possible to add five oranges, two lemons, and seven limes, and get fourteen grapefruit.

This incorrect method is presented first, for the reason that it seems to aid students to realize the value of careful analysis at the outset of the time study. Had the observer kept clearly in mind the unit that had been selected (one assembly), he would have set up his study in this manner:

The worker carried enough castings for 10 assemblies to the bench in 0.4 minutes. The time for Element A is,

$$0.4 \div 10 = 0.04 \text{ minutes per assembly.}$$

The worker carried enough bolts to the bench for 50 assemblies (2 bolts are used for each assembly) in 0.5 minutes. Element B is,

$$0.5 \div 50 = 0.01 \text{ minutes per assembly.}$$

Nuts for 250 assemblies were carried to the bench in 0.5 minutes. Element C is,

$$0.5 \div 250 = .002 \text{ minutes per assembly.}$$

Elements D and E were expressed correctly in the previous example,

$$1.0 \div 10 = 0.1 \text{ minutes per assembly.}$$

and,

$$5 \div 50 = 0.1 \text{ minutes per assembly.}$$

Since all of the figures in this example are expressed in identical terms, it is correct to add them. The correct standard is, therefore:

Element A	=0.040 minutes per assembly.
Element B	=0.010 minutes per assembly.
Element C	=0.002 minutes per assembly.
Element D	=0.100 minutes per assembly.
Element E	=0.100 minutes per assembly.
Total	=0.252 minutes per assembly.

Some may prefer a slightly different method of putting element times on a common footing. The following procedure is used by those dealing with standard data (a term discussed in Chapter 21). It is important that these corrections be made; the method used is of secondary importance.

ement	*Time*	*Element Unit*	*Number of Element Units to a Standard Unit*	*Minutes per Standard Unit (one assembly)*
A	0.040	Casting	1	0.040
B	0.005	Bolt	2	0.010
C	0.001	Nut	2	0.002
D	0.100	Assembly	1	0.100
E	0.100	Assembly	1	0.100
Total				0.252

The unit on which the time study is based usually is the unit which is being used in reporting production. In most cases, trouble is being invited by the observer who selects any other unit. This can be illustrated by expanding the example previously used. Suppose that several operators assembled two bolts and nuts to a casting, and assume that one worker spent his entire time bringing parts to the assembly benches; time standards could easily be set in terms of minutes per truckload of each part, but to do so would necessitate setting up control over the number of truckloads transported. To apply the standard with confidence to the amount produced in a given day, normally would require that some independent agency count and report the correct amount. If the amount trucked in a week, or less, bears no relationship to the number of assemblies produced in the same period of time, it may be necessary to set up such a control. But if there is a close relationship, and if production is being checked and recorded in terms of assemblies, it would be logical to set standards for trucking parts in terms of assemblies. The question might be asked: Why not set the trucking standards in terms of truckloads, then figure daily truckloads from the number of assemblies reported? It is obvious in this example that it is easier, in the long run, to

do the extra calculating at the time the standard is set, and thus avoid extra calculating every time production is reported. It is the responsibility of the observer to choose a unit (1) which can be reported with the least trouble and (2) which can easily be checked for accuracy.

When there is little correlation over short periods of time between trucking and assembling, steps must be taken to set up a reliable method of reporting and checking the production of the trucker. These intermediate controls, as a rule, are not satisfactory. The expense of providing a checker at this point probably would be prohibitive, and mechanical means are easily circumvented by employees and foremen who can gain by falsifying production figures. In one of his classes, the writer mentioned this difficulty in connection with the manufacture of paper cans. It was necessary to set up an intermediate control over the number of cans seamed, as there was a low correlation each day between cans seamed and cans labeled and packed. The seaming crew was paid a bonus on cans produced over standard, so it was to their advantage to boost production figures by fair means or foul. The control involved placing a mechanical counter up near the ceiling over each conveyor, and production figures for each group were found by subtracting the morning reading from the evening reading. Production figures soon mounted phenomenally and the writer discovered, to his chagrin, that the members of each crew took turns, during the noon hour while the machines were shut down, sitting on ladders and keeping the counter going by hand. After the writer had related this example of the difficulties involved in checking production at intermediate points, one of the students in the class, who was employed in the same industry, told of a similar instance. In his case, photoelectric cells were used to actuate the counters, and in his case, too, the production mounted unbelievably. He discovered, however, that during the noon hour each day a worker hoisted an electric fan into position and in a very few minutes the spinning blades had boosted the production count and raised the crew's bonus a dollar, or so, for each worker involved. Employees nearly

always consider such practices legitimate; as a battle of wits and not as dishonesty.

Intermediate production reports often can be checked easily by keeping cumulative records, and by comparing at frequent intervals the accumulated intermediate production with the accumulated final production. The trucker, for instance, who moves parts to the assembly benches can truck many more or many less than are assembled in any one day, but in the long run he cannot truck more than are reported as having been assembled (plus rejects and spoiled assemblies). When it is necessary to get reports on intermediate production, the cumulative record may be the answer to objections that intermediate checking is too expensive. The worker can keep his own daily production records, which are corrected periodically by comparing them with figures on which they depend and which can be checked independently. Under such arrangements the unit for the time standard for trucking would be that which the trucker could most easily count.

DEFINING THE JOB.—The cycle cannot be determined, as we have seen, until the unit has been determined and until the job has been defined. The job is defined through verbal description and by means of sketches. It is at this point that the observer lives up to his title or fails to qualify as such. It may seem at first blush to be easy to watch a person work and write a description of what that person does. But the beginner often writes down descriptions which do not fit the facts, strange as it may seem. Such errors usually arise from the practice of starting the description in the plant and finishing it in the office. An observer recommended that a rubber mat be secured for a worker who stood where grains of sand fell on the floor. It occurred to the observer after he had returned to the office that there was danger that the worker might slip and fall, but though he had observed the man for nearly an hour the fact that he stood on slats, which allowed the sand to fall through onto the floor, had escaped his notice.

While writing the job description, the observer breaks the job down into elements or parts. Although these elements are short, they are not as brief as the components

used in motion study. For purposes of timing, the cycle should be broken into parts no shorter than 0.03 minutes, the shortest time which can be conveniently timed and recorded. Many of these elements are, of course, much longer. A job which has been broken into elements for time study purposes might read as follows:

A—Push empty truck from bench A-5 to elevator #2 (55′).
B—Walk to gate and ring bell.
C—Wait for elevator.
D—Push truck into elevator.
E—Descend from 3rd floor to 1st floor.
F—Wait while gate is opened by operator.
G—Push truck to box storeroom (200′).
H—Load 30 bundles (10 each) of #755 corregated boxes.
I—Push loaded truck to elevator #2 (200′).
J—Walk to gate and ring bell.
K—Wait for elevator.
L—Push loaded truck into elevator.
M—Ascend from the 1st floor to the 3rd floor.
N—Wait while gate is opened by operator.
O—Push loaded truck to bench A-5.

Any adverse conditions, such as poor light, rough floors, slippery spots, etc., should be noted.

A bench assembly description, by way of contrast, is shown as follows:

A—Press treadle and reach for castings (bins L-1 and R-1) with both hands—grasp one casting in each hand and place in fixture—release pressure on treadle.

B—Reach for brackets (bins L-2 and R-2) with both hands—grasp one bracket in each hand and place on castings.

C—Reach for bolts (bins L-3 and R-3) with both hands—grasp one bolt in each hand and start screwing them into tapped holes in brackets.

D—Pull down suspended ratchet screwdriver with one hand and guide the bit into position with the other hand—drive first bolt down and tighten—drive second bolt down and tighten—release screwdriver.

After a proper approach to the department and to the

worker, after analyzing the operation, and after describing it (with the aid of sketches, if necessary), the observer is ready to commence timing the elements.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. How important to the observer is good equipment? Which is more important in making time studies: good equipment, or good judgment and experience?
2. What are the relative advantages of decimal minute and decimal hour stop watches?
3. What three mechanical arrangements are desirable in a stop watch?
4. What is an observation board? Why is it important?
5. What are three advantages in using a printed time-study sheet?
6. What other equipment is useful to the time study observer?
7. What information should the observer secure before approaching the department where a time study is to be made?
8. Should a time-study observer ever be sent into a department prior to the proper introduction of the program to the supervisor and the workers? Explain your answer. What is a "proper" introduction?
9. Should a new observer ever go to work without being introduced to the foreman and to the workers who are to be timed?
10. Why should an observer never start a new time study without the consent of the foreman?
11. Should an observer request permission of a worker to time him? Suppose permission is refused?
12. Would you explain to the worker, if he requested such information:
    a) Why you wanted to time him?
    b) How to make a time study?
    c) What standard you obtained after timing him?
13. Explain carefully what a work cycle is. What two things must be specified or defined before a specific cycle can be determined?
14. Why is it so important for the observer to keep in mind what the standard unit is while he makes the study and calculates the standard?
15. Why is it essential to have a good check on how much is produced by the workers, before time studies are made?
16. What difficulties are involved in checking intermediate production? How can the checker be sure intermediate production figures are accurate?
17. How finely should the work cycle be broken down before the observer begins timing the elements?
18. Distinguish between the components used by the analyst and the elements used by the observer. Why does not the observer use components in making time studies?

Chapter 18

TIMING THE ELEMENTS

After analyzing and describing the operation the elements are timed. Two methods are in popular use: continuous and snap back.

THE CONTINUOUS METHOD.—The continuous method involves noting the watch reading for the beginning and ending of each element without snapping the hands back to zero. If an ordinary pocket watch is used to time the operation, the continuous system must, of necessity, be used. Readings taken by this method would appear as follows:

	Cont.	*Indiv.*	*Cont.*	*Indiv.*	*Cont.*	*Indiv.*
Element A:	1.25	1.25	4.83	1.21	8.24	1.23
" B:	2.60	1.35	5.99	1.16	9.59	1.35
" C:	3.62	1.02	7.01	1.02	10.64	1.05

The individual times for each element are next averaged:

Element A: $(1.25+1.21+1.23)\div 3=1.23$
" B: $(1.35+1.16+1.35)\div 3=1.29$
" C: $(1.02+1.02+1.05)\div 3=1.03$

In this example, the watch has run continuously from 0 to 10.64.

THE SNAP-BACK METHOD.—In using the snap-back method it is necessary for the observer to note the positions of the hands as he quickly depresses and releases the stem at the instant which marks the end of each element and the start of the next. He then "reads" the watch from memory and writes down the reading. Inasmuch as each reading is net, no subtracting is subsequently necessary. Readings taken by this method would appear as follows:

Elements:	A	B	C
	1.25	1.35	1.02
	1.21	1.16	1.02
	1.23	1.35	1.05
Totals	3.69	3.86	3.09
Averages	1.23	1.29	1.03

The total elapsed time often is checked, when this method is used, by noting from a pocket watch the time the study starts and the time it ends. If the total time need not be accounted for, time can be taken out by depressing the slide at the side of the stop watch, thus freezing the hands until the delay is over, when, by raising the slide, the hands are released to continue timing the element.

The writer favors the snap-back method wherever it can be used. It is simpler and allows the observer to concentrate better on the operator and the job at hand. Less work and time are subsequently required in calculating the time standard, too.

POSITION OF THE OBSERVER.—The observer should stand where he can see the operator's hands. This is particularly important if the observer must note the beginning and ending of each element in the study by sight rather than by sound. The inexperienced observer usually wonders how it is possible to keep one's eyes on the operator and on the watch at the same time. To avoid too much eye strain, most observers, choose, if they can, elements which begin and end with a sound. Burring operations are, for instance, easy to time; as the worker finishes each part he drops it, and the sound marks the end of one cycle and the start of the next. Timing by sight is, however, not very much harder than timing by sound. If the watch is held in the line of sight from the eye of the observer to the hands of the operator, it is a simple matter to move the eyes from the operator to the watch the instant the end of the element is reached, snapping the watch back simultaneously. The position of the hands on the watch is mentally noted and immediately recorded. If the end of an element is marked by a pronounced movement on the part of the operator:

kicking a treadle, releasing a suspended tool, turning a machine control, etc., the observer can easily catch the exact time by looking at the watch and noting the characteristic movement in the periphery of his eyes. The proper position of the observer is shown in Figure 39.

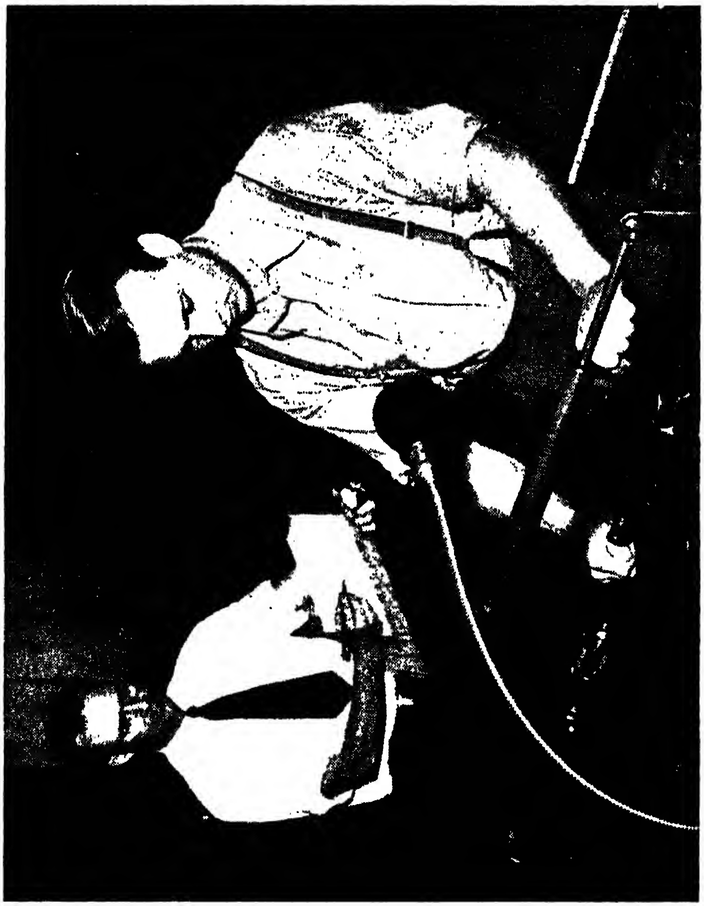


FIG. 39—*Proper position of the observer.*

THE TYPICAL TIME.—Timing operations in a plant or office is, in reality, a process of sampling. The chemist who is asked to report on the physical and chemical characteris-

tics of a carload of wheat, coal, or grease, does not use the whole carload in the process of testing. A relatively small, but *adequate* and *representative* sample, will yield the same results as would result from testing the entire batch. Obviously, if we are testing for moisture content of a carload of coal, the correct figure can be obtained by weighing the carload of coal, drying it out completely, and weighing again. The difference would be moisture content, and if expressed as a per cent of the heavier weight would represent the correct percentage of moisture. Likewise, we might repeat the process with half a carload. If the coal was mixed thoroughly, then divided into two parts, the percentage of moisture found for one half would be almost exactly the same as that found for the other half. As we reduced the amounts tested, however, a point would be reached where successive samples taken from the same car would deviate rather widely. Such samples are said to be inadequate. Two adequate samples from the same lot will yield approximately the same results.

Samples must not only be adequate, they must be representative, as well. Representative samples of coal are secured by choosing small quantities from scattered sections of the pile. This procedure makes it unnecessary to mix the coal before taking the samples.

How does this apply to time study? An adequate sample of time must be secured, and the performance timed must be representative. The operator must work, during the timing, as he always works—he must not change his methods. If the materials, or other factors, are such as to introduce appreciable time variations in successive cycles, more cycles must be timed, in order to obtain an adequate sample, than would be the case if the variations were small.

In making the time study, the operator judges from variations in the corresponding readings of successive cycles, whether he needs many or few figures. To be certain he has an adequate sample, the observer may separate each column of readings into two parts. If the average of one part is more than five per cent higher or lower than the average of all of the readings, more cycles need to be timed. The figure five is used because it is generally conceded that

experienced time-study observers are likely to secure time standards which are in error by that percentage. This method is illustrated as follows:

First study:					
1.	.24	1.	.24	2.	.25
2.	.25				
3.	.24	3.	.24	4.	.26
4.	.26				
5.	.28	5.	.28	6.	.30
6.	.30				
7.	.26	7.	.26	8.	.32
8.	.32				
			1.02		1.13
	2.15				
Average	0.27	Average	0.255		

The average of readings 1, 3, 5, and 7 is more than 5% less than the average of all of the readings.

Second study:					
9.	.32	1.	.24	2.	.25
10.	.30	3.	.24	4.	.26
11.	.22	5.	.28	6.	.30
12.	.27	7.	.26	8.	.32
13.	.30	9.	.32	10.	.30
14.	.31	11.	.22	12.	.27
15.	.24	13.	.30	14.	.31
16.	.26	15.	.24	16.	.26
	4.37		2.10		2.27
erage	0.273	Average	0.263		

The average of readings 1, 3, 5, 7, 9, 11, 13, and 15 is about 4% less than the average of all of the readings.

The favorite method of getting a typical reading for a given element is to use the arithmetic mean (average) of all of the readings for that element. For instance, 0.273 would be considered as being the typical reading in the above example. Some observers, however, prefer to use other meth-

ods. Some of these are: (1) estimated typical reading, (2) median, and (3) mode.

The estimated typical reading eliminates practically all calculation, for the observer encircles a figure which he considers to be typical for each element, and all of the other figures are ignored. The median is found by taking the middle figure after all readings for a given element have been put in order of magnitude. The mode is the figure which actually recurs most frequently. There are several advantages and disadvantages to the use of each of these methods, but one disadvantage, common to all three, serves to rule them out for many kinds of work: extremes do not make themselves felt. Perhaps conditions are such that more time is occasionally required by the operator. This time will not be allowed if the typical element is chosen by using the median, or by using the mode.

An example will make this clear.

	Readings
1.	1
2.	1
3.	1
4.	1
5.	1
6.	2
7.	2
8.	2
9.	5
10.	10
	26

Average: 2.6

Estimated typical: either 1 or 2, probably, in most cases, 1.

Median: 1.5

Mode: 1.0

This example is admittedly extreme, but it illustrates the strength of the arithmetic average as a means of finding the typical reading.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Describe the continuous method of timing, and present as many advantages and disadvantages as you can in its use.
2. Describe the snap-back method of timing, and present as many advantages and disadvantages as you can in its use.
3. For best results while timing an operator, where should the observer stand and how should he hold his watch?
4. "A time study is an example of sampling." In what way?
5. What two precautions must be taken in order to secure a good sample?
6. How can the observer be sure he is getting a representative sample, or performance?
7. How can the observer be sure he has secured an adequate sample, or enough readings?
8. What is meant by a typical reading, and how is it secured?
9. What are the advantages in using the estimated typical reading, the median, and the mode? What disadvantage is common to them all?

Chapter 19

ESTIMATING SPEED RATES AND DETERMINING ALLOWANCES

In the preceding chapters we have learned how to determine the work cycle, how to analyze it, and how to time it. It would seem, off hand, that nothing more is needed to determine a time standard. Unfortunately, however, the hardest part of time study work is yet to come.

THE NEED FOR RATING.—Let us assume that the following observed readings have been secured for processing ten pieces:

.17
.15
.20
.16
.19
.16
.20
.18
.15
.17

1.73

We assume, therefore, that the time standard is 0.173 min. per piece. Wishing to check our figures, another study is made on another operator performing the same job. This time the figures are:

.10
.11
.10
.09
.12
.11
.10
.10
.09
.10
——
1.02

One observer might conclude that the first sample was not adequate, and that the two studies should be averaged. $(1.73+1.02)\div20=.1375$ min. per piece. More studies might indicate that most of the operators perform more slowly than either of the two already studied. Furthermore, a recheck of the first operator shows considerable variation in studies made in the morning and late in the afternoon, on Monday and on Friday, in summer and in winter. To get a completely satisfactory time study, then, it appears that samples will have to be taken (1) from performances of a great many operators, (2) at all hours of the day and night, (3) every day in the week, and (4) during every season. We could add many other factors which influence performance. (More will be mentioned later.)

It is obvious that it is impracticable, if not impossible, to get a statistically accurate average time for all workers operating under all possible conditions. The answer is, perhaps, to find an operator working at a normal rate of speed under normal conditions at a normal time of day during a normal season. But this procedure is equally futile.

It was to meet the need of somehow resolving the inconsistancies in performance that the technique of speed rating was devised. Speed rating is a subjective process which involves comparing the observed performance with the operator's own concept of a normal performance. Let us return to the two sets of observations previously used. If,

as the observer timed the first operator, he had thought to himself: "This man is working at a tempo which is slower than normal—I should say about 20% below my idea of normal," we could translate the observer's figures into something tangible. The actual, recorded time was 1.73 minutes. But, the time is in excess of that which would be required by a worker performing at normal speed. If the tempo estimate is 20% below normal, it is convenient to assume that normal is 100% and that the operator in question performed at a comparative speed of 80%. It is clear that a person who performs at low per cent efficiencies requires more time than those who perform at higher per cent efficiencies. The percentage, then, varies inversely with the time required. To "normalize" the typical reading in the first example cited we would use the following formula:

$$\frac{\text{Observed reading}}{\text{Normalized reading}} = \frac{\text{Normal tempo (100\%)}}{\text{Estimated tempo}}\text{,or}$$

normalized reading = observed reading × estimated tempo (expressed as a per cent) ÷ 100.

The typical reading was 0.173 minutes, the speed rate or efficiency percentage was 80%, so $0.173 \times \frac{80}{100} = 0.1384$ min.

To use the same procedure with the second study, the observer might subjectively estimate the speed rate of the second operator at 135% (35% faster than normal). Using the same formula, the typical reading, 0.102, multiplied by 1.35 equals 0.1377 min. per piece. For all practical purposes the standard, as found from either study, would be 0.14 minutes per piece; and we see that with the exercise of a little judgment the observer has secured a standard without wasting time on almost endless observations in order to secure a good average of performances under all sorts of conditions.

JUDGMENT OF THE OBSERVER.—The reader might object, first, that by timing a great many operators an objective standard could be secured, and it would be unnecessary to resort to a subjective "speed rate" factor, which, at best, is little better than an "educated guess" on the part of the ob-

server. Inasmuch as it is clear that an adequate timing of a great many operators working under varying conditions is impossible to obtain in practice, it follows that we either must find someone who is working at exactly a normal tempo, and time him, or the actual times of operators working slower or faster must be "normalized" by the application of speed rate factors. A little reflection will convince the reader that subjective judgment is used in either case. How else would a normal tempo be recognized? It is no more or less difficult to judge a normal, or 100%, performance than it is to judge a 110% or a 90% performance. If this is the case, it is obviously futile to wait for a normal performance before securing a time standard of a given operation. Students frequently insist that the "guesswork" in time study can be eliminated by timing only normal performances. But they conveniently forget that anyone's concept of what is a normal performance is a matter of judgment, and that the spectre of "guesswork" must inevitably haunt the observer, no matter how he arrives at his standard. Judgment *can* be eliminated if past experience is used as a basis for the calculations, but the proven unreliability of such standards rules this method out of our discussion here.

TIME STUDY AND SCIENCE.—It is frequently contended that time study is not scientific, because subjective estimates serve to modify the recorded times. If those who make such statements have in mind the invariable quantities of oxygen which will unite with given quantities of hydrogen to form water, and similar illustrations from the physical sciences, then time study is not a science. But if the presence of subjective elements militates against the scientific aspects of a profession, then practically no calling can be said to be scientific. To the extent that time study is amassing a body of organized knowledge, to be drawn upon in lieu of individual experience and the whim of the moment, we can say that it is scientific. Observers who learn about principles which are gradually being formed, and who practice these principles and attain skill in their use, are following the art of time study.

THE "ABSOLUTE" TEMPO.—The writer frequently demon-

strates a simple assembly operation before his time- and motion-study classes, and asks the students to rate him. Their estimates may vary, for instance, from 100% to 130%, and, after they are tabulated on the blackboard, the inevitable question is: "Those are *our* estimates; now what is the *right* answer?" That is a question the instructor has never been able to answer. Where judgment is involved, there can be no exact answer, only central tendencies.

Although there is no absolute criterion against which the time study observer can check his judgment of tempo, he can develop an amazing (to the uninitiated) consistency in rating performances of varying speeds. It is essential that observers develop this ability, for a lack of consistency of judgment results in unreliable standards. Such standards, when used as a basis for an incentive or labor control system, result in more or less widely fluctuating results over a period in which the operator exerts a constant amount of energy but works on several different jobs. Or, it may be, one operator, performing one job works much harder for a given bonus or efficiency than his fellow worker who happened to draw a job with a "looser" standard.

The presence of "tight" and "loose" standards in an organization causes almost as much dissatisfaction as a policy of rate-cutting. Consequently, it not only is essential that observers, as individuals, train themselves to be consistent judges of tempo, but they must train themselves to be consistent as a department. Furthermore, the department must be consistent over a period of time. Standards set this year must not be "tighter" or "looser" than those set last year and the year before that. Thus, it is seen, a real need exists for some absolute tempo against which observers can check their judgment from time to time.

The head of every standards department should establish several standard operations for members to check against regularly. It is important that the methods used in performing these operations be defined carefully and adhered to without variation, or the resulting rates will be valueless. There is some tendency toward following Mr. Ralph Presgrave's suggestion[1] that walking and card-dealing

[1]Found in *Advanced Management*, July-September, 1943, p. 104.

be used for practice, and that standard speeds be considered, respectively, as 3 miles per hour and 52 cards dealt into four piles in 0.5 minutes. Even for simple operations, such as these, arguments arise concerning method. Since it is essential that no changes be introduced in successive demonstrations, it is important to walk and deal consistently. If the demonstrator is changed from a six-foot man to a short girl wearing shoes with high heels, the question arises: Is there a change in method? There is a tendency to confuse *effort* with *results*, and since the girl walks with greater effort than the taller man, there is a tendency to over-rate the girl's walking speed. Likewise, in dealing cards there are unconscious variations in method. One demonstrator will swing his arm as he places the cards, while another will flip them with a quick wrist motion. Even one demonstrator tends to change from the former to the latter method as he picks up speed. So, for purposes of checking consistency of judgment, all variations of method should be left out of the demonstrations. The group of walking demonstrations should be confined to one person, and he should not vary the length of his steps as his speed changes in successive performances. The card dealing, likewise, should be done by only one demonstrator during the session, and he should be careful during successive demonstrations to (1) swing his arm the same amount, (2) place the piles exactly the same distances apart, (3) place the cards on each pile with the same neatness. If the cards are placed neatly one time and thrown carelessly the next time, the observers cannot rate the demonstrations with any degree of profit. The demonstrator should not change his method in dealing the last card, either. During slow performances, demonstrators often pass the last card from the left hand to the right hand and then place it on the pile. For fast performances the left hand simply drops the last card as the right hand is dealing the next to the last card. In other words, the last two cards are dealt in rotation in slow demonstrations and simultaneously in fast demonstrations.

It is true that the observer must allow for such small changes in method in the shop, but we are now discussing

an absolute tempo standard, and since time of performance varies both with changes in method and with changes in effort, we *must* keep one constant while judging the effect of variations in the other.

Mr. Presgrave suggests that the controlled walking demonstrations be conducted (1) over a 44-foot distance, to be covered in the standard time of 10 seconds, (2) over a 52.8-foot distance, to be covered in 0.2 minutes, or (3) over a 47.5-foot distance, to be covered in 0.003 hours. In each case, the speed amounts to 3 miles per hour. The card dealing demonstration (not including shuffling, of course) is conducted with (1) 30 seconds, (2) 0.5 minutes, or (3) 0.00833 hours as the standard speed.

CONSISTENCY OF JUDGMENT EXPECTATION. — What per cent of error should be expected of a skilled observer? Estimates of the consistency which should be expected vary. Good observers can set standards on different workers doing the same work, but at different speeds, which do not vary from their averages more than 5%. Some observers can consistently hold their percentage of error down to 3%. Judging speeds of walking and card dealing demonstrations is harder, because of the relatively short samples of time on which opinions can be based. Consequently, it can be said that observers who can consistently judge such demonstrations with maximum percentages of error of 10% are satisfactory.

The per cent of error is calculated as follows:

Case 1: An observer estimates the rate of speed in a card dealing demonstration at 110%. The operator actually dealt the 52 cards into four piles in exactly 0.5 minutes, thus performing at 100%. The error is 10%.

Case 2: An observer timed two operators performing identical jobs. The first standard was 0.684 hrs. per 100 units. The second standard was 0.756 hrs. per 100 units. The per cent of error is measured from the average of the two standards, for we have no absolute figure against which to check. The average is 0.720. The deviation from 0.720 is 0.036. The per cent of error is $0.036 \div 0.720 = 5\%$.

THE RATE OF EFFECTIVE SPEED.—Some writers advocate, and some observers practice, the breaking of speed rates

down into their elements. For instance, it is assumed that if the conditions surrounding the job, the skill of the operator, his consistency or lack of consistency, and his effort, all affect his speed, a more accurate standard can be set if the observer rates each of these factors separately. More frequently, observers rate speed and skill separately. In the opinion of the writer, observers who follow such procedures are living in a fool's paradise. They are "kidding" themselves into believing they are obtaining more accurate standards, when, as a matter of fact, they are setting the stage for error. Observers who rate skill are doing so in terms of speed. Those who rate effort are going off on a tangent—and the main purpose of the rating factor is being forgotten. The speed rate is supposed to modify the watch reading so as to exactly compensate for variations under or over normal accomplishment. Every time standard includes two factors: time and production. It should be obvious, also, (but this fact is often forgotten) that a time standard should be set only on a standardized job, one acceptably performed under standard conditions by correctly trained workers using the correct methods. Let me repeat: *Before* a job is timed for purposes of setting a time standard the following factors must be standardized and kept that way while the study is in progress:

a) The correct method should be described and the operator *must* follow that method, exactly, while he is being timed.

b) The quality of work to be performed must be specified, and during the time study the operator *must* produce work which is neither better nor worse than that specified.

c) The operator *must* be normally skilled. Sub-normal operators (those not qualified to do the work, or beginners) should not be studied by the observer. Neither should super-skilled operators (whose talents are being wasted on work that is beneath them) be timed for the purpose of setting standards.

d) The conditions under which the operator works are a part of the job, and tend to influence productivity. So, while the job is studied, conditions *must* be the same as those which normally obtain.

If any of these factors subsequently change, the standard should be changed, for the job is no longer the same.

Nearly everyone concedes that standards should change when methods change. Normal speed for plowing an acre of land with a tractor is not to be compared with doing the same job with a horse—nor with spading it by hand.

Work of exceptionally high quality is more time-consuming than is work of low quality. A time standard cannot be set until the degree of quality has been established. Every worker will concede—every employer should—that changes in quality standards, resulting in better workmanship, should be followed by greater time allowances. Every employer wants to cut time standards when quality standards are lowered—and employees should not object. Quality standards are inherent in the job. Change the quality, and you change the job.

Fewer will concede that skill specifications form an integral part of the job. But employers are coming to recognize that skills can be measured, and that the right operator should be put on the right job. Every job should specify the kind and degree of skill that should be possessed by those who perform it. That kind and degree of skill should comprise an integral part of the job. When a different kind and degree of skill is specified for a given job, the job has changed and a new standard should be set. Because a beginner is working on a given job does not mean that there should be a "beginners' standard." Job standards and time standards refer to the job, not to the worker.

There is considerable confusion regarding skill, and what it is. Skill is made up of a mixture of intelligence, knowledge, and dexterity. Intelligence is innate, we are born with or without it and there is nothing that can be done about it subsequently (except, possibly, the first few weeks of life). Knowledge can be acquired by unintelligent people, but their ability to apply it is limited. Intelligent people, without facts (knowledge) have little to work with, but they work exceedingly well with what they have. Dexterity is both innate and acquired. A person with limited manual dexterity can learn to play the violin or piano, but ten hours a day of practice will not make such a person into

another Fritz Kreisler or Artur Rubenstein. Dexterity, alone, does not make for skill. A dexterous worker is proficient, but not necessarily skilled. Proficiency comes with practice. Skill results when a proficient worker mixes knowledge and intelligence with his proficiency. A person is skilled, then, to the extent to which he possesses proficiency and knowledge, and the intelligence to apply them to his work.

Workers are usually paid on the basis of the skill they possess. Highly skilled workers are not used for mediocre jobs, nor are mediocre workers placed on jobs calling for a high degree of skill. There are exceptions, however, to this statement. Temporarily, many misfits exist in industry, but in well-managed concerns they are eventually transferred. Those with higher skill than necessary will be promoted, or they go where their abilities are recognized. Learners either improve to the point where they do acceptable work or they are put back where they formerly worked, or they are discharged.

What is the observer to do if job specifications call for a degree of skill not possessed by any of the workers in the department? Set the time standard on the basis of standard skill, or on the basis of existing skill? If the time standard is set on the basis of existing skill, no allowance will have to be made for differences in skill. If a standard is set on a beginner, say, and the observer "normalizes" the actual time for a beginner, then normalizes again so as to shift the normal time for a beginner down to the normal time for a skilled worker—the observer is not only courageous, he is reckless. Observers are supposed to be self-confident, but those who adjust observed times to allow for skill are abusing the term. An observer who was skilled in a given trade could come the closest to making a satisfactory adjustment of this nature. One writer, cognizant of the problem of skill, has gone so far as to insist that observers be able to perform skillfully every job they time study. Anyone who knows what a bewildering array of jobs exist in the modern factory cannot seriously advocate that every observer be prepared to demonstrate up to standard speed each job he studies. It would be about as foolish to expect the designer

to build the part, the architect to do the plumbing, wiring, etc., or the photographer to construct everything he photographed. So the obvious answer to the above question is that existing skill should be time studied and the job specifications should be changed. If high standards are set for mediocre skill, the results are ludicrous. If labor control and wage incentive systems are in use, the standards are definitely unfair to the workers. This procedure is like telling a six-year-old boy you will punish him if he does not jump over a stick and that he will get a piece of candy if he does jump over it, and then placing the stick at a height which a man can just manage to jump by exerting himself. Time standards should be so set as to allow normally skilled operators, working under an incentive system, to average from 125 to 135% efficiency. Effective speed measures results in a given period of time. The time-study observer is not interested in effort; he is interested in the results of normally skilled workers, working under standard conditions, doing acceptable work in the right manner. He is interested in the number of units produced in a given time. He rates the speed with which these units are produced, and he should not try to rate anything else.

Rating the Exceptional Cases.—Those who purport to rate skill use the same line of reasoning we previously used in connection with speed rating, which was: Speed is rated because we find it difficult to find examples of normal speed. They go on to reason: If it is not necessary to time a normal rate of production, but just to time any rate and adjust it back to normal—it must follow that we can:

1. Time an unskilled or a super-skilled operator and "adjust" for his variation from normal.

2. Time a worker pushing a wheelbarrow through a foot of snow and "adjust" the time to compensate for bad conditions.

3. Time an inconsistent performance and "adjust" the time so as to get the time for a consistent performance.

4. Time a performance which exhausted the operator and make an "effort adjustment" so as to get just the right time required for normal expenditure of effort.

And so on. To reduce this whole matter of rating to an absurdity, let us:

5. Time a worker using the wrong method and "adjust for method" so as to get the normal time required for the right method!

This fallacious line of reasoning stems from the belief that speed, rates, qualities, methods, etc., are all in one class. They differ in this respect: the manufacturer specifies quality, method, skill, and conditions. He then tries to find, when other things are normal, what the normal time should be. But he does not expect the worker to work at just that speed. The worker must maintain quality, follow directions concerning methods and procedures, and work under certain conditions; these matters influence speed, and *they must be standardized* before the normal standard for speed can be determined.

One more reason why speeds can and should be adjusted, while other factors should not. Workers are willing to use standard methods and maintain standard qualities; the employer can standardize conditions; but workers will not and, more frequently, cannot produce at unvarying rates of speed, at least for any length of time. Incidentally, most variations in speed from normal can be estimated closely, while the effects on performance of other factors are very hard to determine.

EFFORT RATING.—It has been said that if all factors of a job are standardized, the variations in speed can be accounted for only on the basis of effort. This probably is true, if *all* factors are standardized. But to use "effort" as the criterion, instead of "effective speed," is dangerous. Some people can put considerable effort into a job and do very little, even without deviating from the correct method. This may be the result of lack of skill, nevertheless it is true. If the observer picks a worker who does an acceptable job, who is just skilled enough, and who uses the correct methods, he would do well to put the emphasis on effective speed rather than effort. We can note and judge the rapidity of accomplishment (effective speed); we are dealing with a vague quality when we talk about "effort."

DECEPTION BY THE OPERATOR.—Observers frequently are

deceived by clever workers into setting loose standards. If the program has not been properly introduced, this is a real problem for the observers. The workers feel that a system of labor control is being set up to check on them, so they will try to make the standards as loose as possible. Or, if there is a bonus system in effect, loose standards mean more bonus money for the workers. It is a game, or a form of collective bargaining. Management tries to beat the standards down (i.e., times allowed are reduced as far as possible) and the workers do all they can to raise them. Standards set under such conditions are of doubtful value. Collective bargaining can be applied to base wage rates, the share of the savings to go to the workers, and so on, but time standards (or standards of any kind for that matter) should not be made the subject matter for bargaining. Standards can easily be checked for accuracy and consistency in most cases. If a worker, unknown to the observer, changes a gear ratio to slow down his machine, or betters the quality of his work, or does unnecessary work, these cause a loose standard. Every standard should be checked against similar standards and against past production figures before being put into effect. If, for instance, a standard were established while an operator produced at a rate of 100% and if this standard showed 150% daily efficiency for the same operator when applied to his past production records, it would be obvious that someone had been badly fooled. Every observer has been so treated, and that is no disgrace—but it is a disgrace to let a loose standard (or a tight one) go through without careful checking.

ALLOWANCES.—It is considered to be good practice to charge against each worker the total time he spends in the plant, exclusive of lunch time. That the worker may have credit for time for personal needs and for recovering from fatigue, an allowance is added to each standard. These allowances should be determined carefully and applied with judgment. Allowances are determined somewhat as follows:

On the average, it is found that a normal person in a given department requires 23 minutes per 8-hour day for trips to the drinking fountain and the toilet. If we subtract

23 minutes from 480 minutes (entire working day), the remainder is 457 minutes (net working day). The per cent allowance which must be added to 457 to give 480 is 5, i.e., 457×1.05=480. This 5% personal allowance forms the basis and irreducible minimum allowance. To the personal allowance is then added other varying amounts of time, depending upon the nature of the job. As a result of time studies on soldering operations, for example, it is found that workers rest six minutes out of every hour worked. The men, on the other hand, who skin cattle in a packing house, might have to rest 10 minutes out of every hour worked. In the first case the allowance would be calculated as follows:

Minutes in total working day	480
Personal allowance	23
Minutes in net working day	457
Additional resting time	46
Minutes in effective working day	411

480÷411=1.17
Total allowance = 17%

In other words, if a worker spent 411 minutes working, during an 8-hour day, his allowances of 17% should bring this time up to 480 minutes: 411×1.17=480.

In the second case, the calculations would be as follows:

Minutes in total working day	480
Personal allowance	23
Minutes in net working day	457
Additional resting time	73
Minutes in effective working day	384

480÷384=1.25
Total allowance=25%

These allowances, when added to the net times worked, tend to compensate the worker for the time he must spend

away from the job and in idleness. They are not calculated separately, but are set up in advance of the individual study and are applied with judgment. If it is found, for instance, that no rest is needed for a desk job, 5% only is allowed. If walking 100 ft. requires 2% more, 7% is considered to be the standard allowance for walking. Likewise, pushing moderately heavy loads in a hand truck may require 15%, doing the same on slippery floors 20%, tending a machine may require 10%, but if concentration and attention are demanded, an extra 5% may be required. If a time standard is being found for the following job, the allowances would be applied as follows:

A. Push truckload of material—	Normal time×1.15%
B. Feed material into machine—	Normal time×1.10%
C. Walk to desk—	Normal time×1.07%
D. Make out job ticket—	Normal time×1.05%
E. Push finished material over slippery floor—	Normal time×1.20%

Allowances, as can be seen from the above example, are applied separately to each element just as speed rates are applied. Theoretically they should be applied to normal times, but it makes no difference, mathematically, in what order they are applied.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Explain the theory of speed rating.
2. What is the chief value of rating the speed of the operator?
3. Distinguish between "effort" and "effective speed."
4. Why is it important that each time standard should require an amount of effort consistent with that required by other time sandards in the plant?
5. How can a standards department head be sure the time standards being set from day to day are consistent?
6. If an observer made two time studies on the same job and got 9 hours per 100 units on one and 11 hours per 100 units on the other, what was his per cent of error? Should an experienced observer be able to do better?
7. What four factors must be standardized and kept constant before an accurate time standard can be established?

8. What is meant by skill? Proficiency?
9. Why is it difficult to rate skill?
10. Would you attempt to rate an operator who used the wrong method?
11. State in detail how you would protect yourself from being deceived by an operator during the course of a time study.
12. Under what conditions would workers feel they should practice deception while being observed during a time study?
13. What allowances customarily are added to each time standard?
14. Do not allowances introduce errors into otherwise accurate time standards?
15. How are fairly accurate allowances determined?
16. Should blanket speed rates and allowances be applied to entire jobs, or should each element be rated separately?

Chapter 20

ESTABLISHING THE TIME STANDARD

We have considered, up to this point, all of the ingredients which go into a time standard: the analysis and description of the job, the determination of the cycle, the unit of production, the rate of speed of the worker, and the allowance to be added. The calculation of the standard can now be undertaken.

AN EXAMPLE OF A SIMPLE CALCULATION.—It has been stated previously that the time-study form is built around the needs of the industry. One of the simplest arrangements is that which provides vertical columns for the watch readings, with space at the top of each column for identification of the elements, for speed rates, and for allowance factors. Calculations are made on a work sheet, and the standard and a complete description are shown on a head sheet, both of which are attached to the time-study form.

If, for example, we have a time study on trucking 50-lb. boxes of a finished product to the shipping dock, the head sheet, time-study sheet, and work sheet would appear as shown on pages 228, 229, and 230, respectively.

MACHINE STANDARDS.—When an operator pushes a truck, assembles parts, or performs other manual work, there is not much doubt concerning what the time standard should be. But how should a standard be established for a man who merely watches an automatic machine? Should the standard be set on the machine, or on the man? Sometimes these questions are difficult to answer. Much depends upon the use to which the standards will be put. For instance, if the standards are used chiefly for production control and cost purposes, machine time is more important. On the other hand, if the standards are used for labor control or as the

HEAD SHEET

Date: March 23, 1945. Standard No.: S-155A

Description of job: Hand truck 50-lb. boxes of #855 from packing dept. to dock B.

	Description of Elements	*Time*
A	Place 30 50-lb. boxes of #855 on type XX truck	0.244
B	Push loaded truck from packing dept. to dock B (150 ft.)	0.144
C	Push empty truck back to packing dept. (150 ft.)	0.132
	Total minutes per box	0.520

Hours per 100 boxes : 0.87

Boxes per hour :115

Observer: N. A. Danley

Head Standards Dept.: Lowell N. Gwenn

Plant Superintendent: Frent Mack

TIME-STUDY SHEET

Elements	A	B	C			A		
Speed Rates	120	130	130					
Allowances	115	120	110					
	.15	2.71	2.70			.19		
	.16	2.90	2.90			.20		
	.15	2.69	2.78			.20		
	.14	2.80	2.70			.21		
	.17	11.10	11.08			.18		
	.17	4 trips	4 trips			.17		
	.16					.24		
	.15					.22		
	.16					5.30		
	.13					30 bxs.		
	.17							
	.18							
	.14							
	.15							
	.16							
	.16							
	.15							
	.20							
	.22							
	.21							
	.21							
	.20							

WORK SHEET

$$A - \frac{5.30 \times 1.2 \times 1.15}{30} = 0.2438$$

$$B - \frac{11.10 \times 1.3 \times 1.2}{120} = 0.1443$$

$$C - \frac{11.08 \times 1.3 \times 1.1}{120} = 0.1320$$

0.5201 min./box

$$\frac{0.5201 \times 100}{60} = 0.867 \text{ hrs./100 bxs.}$$

$$\frac{100}{.867} \left(\text{or } \frac{60}{.5201}\right) = 115 \text{ boxes/hr.}$$

basis for a wage incentive system, the emphasis would be placed upon keeping the workers profitably occupied.

A simple method for computing time standards for automatic or semi-automatic machines involves equating the machine capacity to some percentage, say 150%, then determining what the output of the machine would be for 100%, or normal production. If a punch press made 117 strokes per minute, a machine standard satisfactory for most purposes, would be set as follows:

$$\frac{1.00 \times 1.5 \times 1.1}{117} = .0141 \text{ min./blank}$$

INTERNALS AND EXTERNALS.—Many automatic machine operations do not require much attention from the tender. If standards are required for labor control or wage incentive purposes, a fairly complex problem presents itself. It not only is important that the machine tender be kept busy, but it is important that the machine be kept running with a minimum of shut downs. Correctly set standards will tend to bring about both results. The problem is to change as many elements as possible from externals to internals. An external is performed while the machine is shut down; an internal while the machine is running. Paper slitting is an example. The element descriptions are:

A—Push empty truck to pile.
B—Load roll onto truck. (Each roll weighs from 300# to 600#.)
C—Push loaded truck to slitting machine.
D—Remove cover from roll.
E—Move roll to position near machine.
F—Set up roll and thread paper through machine.
G—Machine time. (Machine unwinds paper from roll, cuts it lengthwise into narrow ribbons, and winds the slit paper at the other side of the machine.)
H—Paste ends.
I—Mark slit rolls.
J—Separate slit rolls.
K—Pile slit rolls.
L—Clear mandrel and re-set bar.
M—Unavoidable delay.

A standard which considered all elements as externals

would be too loose in practice. In the following arrangement all of the elements are so treated:

Elements	*Min./Lb.*
A	.0010
B	.0005
C	.0012
D	.0003
E	.0002
F	.0007
G	.0172
H	.0005
I	.0005
J	.0009
K	.0006
L	.0001
Total	.0237

It is clear, however, that too much time has been allowed when it is shown that the slitter will run automatically enabling some of the work to be performed as internals. A better arrangement is shown below.

	Minutes per Pound		
Elements	*Machine*	*Internals*	*Externals*
A		.0010	
B		.0005	
C		.0012	
D		.0003	
E		.0002	
F			.0007
G	.0172		.0172
H			.0005
I			.0005
J		.0009	
K		.0006	
L			.0001
M		.0125	
	.0172	.0172	.0190

The standard in this example becomes the sum of the externals plus the machine time, or 0.019 min./lb. Assuming this to be the correct standard, the first one calculated (with all elements treated as externals) was nearly 25% too loose. No matter how the standard is calculated, the operator probably would do part of the work while the machine ran. It is the duty of the observer, then, to determine how much should be treated as internals and how much should not. It may well be that it is not safe to allow the machine to run while the operator goes for materials. Should something go wrong he would be too far away to shut off the power. Under such circumstances the observer investigates the possibility of equipping the machine with an automatic stopping device before he treats such elements as A, B, and C as externals. As the standard is now set up, the operator gets a new roll of paper, removes cover, places roll in position, separates previously slit rolls, and piles them while the machine runs. For a 300-pound roll, the lightest he handles, he still has waiting time amounting to 300× 0.0125, or 3-¾ minutes.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What is the purpose of
   (a) The headsheet?
   (b) The time-study sheet?
   (c) The work sheet?
2. Would you advocate using a time standard for punch-press operators which was calculated with capacity of the machine set at 150%? Would the purpose of the standard influence your answer?
3. In time study work
   (a) What is an internal element?
   (b) What is an external element?
4. How does the observer determine whether an element is an internal or an external?

Chapter 21

STANDARD DATA

To save the time of observers, a standard data file should be set up either prior to or simultaneously with the establishing of time standards. The standard file simply provides a system of cross indexing which enables members of the standards department readily to find and use in new standards the elemental times which already have been determined.

ADVANTAGES IN THE USE OF STANDARD DATA.—Assume that three standards must be established. The first job to standardize is "deliver bushings":

A. Get tote box (5′)
B. Walk to storeroom (50′)
C. Wait for requisition to be filled
D. Carry bushings (25#) to bench (50′)

The second job is "change jobs":

A. Walk to despatcher's cage (175′)
B. Hand in instruction card and wait while old job is stamped out and new job is stamped in—get instruction card for new job.
C. Walk back to bench (175′)

The third job is "carry samples from #1 chip machine to laboratory":

A. Carry can of chips (1 lb.) from #1 Machine to Elevator A (250′)
B. Ring and wait
C. Walk into elevator (6′)
D. Descend two floors
E. Walk to laboratory (300′)
F. Leave sample and walk back to elevator (300′)

G. Ring and wait
H. Walk to elevator (6′)
I. Ascend two floors
J. Walk to #1 chip machine (250′)

How should an observer time these jobs? Should he faithfully plod along behind walking workers through interminable jobs? Or is there an easier way? There is not only an easier way, there is a more accurate way. When an observer must time an operator who walks intermittently, there is a tendency to get an inadequate sample of time, hence successive standards containing walking time are likely to be erratic. Time can be saved and greater consistency will result if standard walking times are established from adequate studies on walking performance under varying conditions: on different kinds of floors, with the operator carrying varying weights, etc. It may be that the observer who is assigned to standard data will arrive at 0.00379 min./foot as standard walking time for workers without loads. Perhaps, too, it will be found that walking time is greater by 10% for successive ten-pound loads carried by the worker. These data can be expressed in the form of graphs, formulae, or a table, and they are filed under the head of "Walking." On the other hand, the three standards mentioned above, which consist largely of walking time, are filed by departments and by job numbers.

In using standard data, care must be used to see that the conditions surrounding the job are the same as those which existed when the standard data were established. Assuming that this matter has been checked, the observer would determine standards for the jobs described above as follows:

Deliver bushings:

A. Walk 5′ (0.00379×5)	0.0190
B. Walk 50′ (0.00379×50)	0.1895
C. Wait (standard waiting times should, also, be established)	0.5000
D. Walk 50′ with 25# load (0.1895×1.20)	0.2274
Total	0.9359 min.

This standard could be expressed as 0.94 min. per trip, or converted to time per pound or per piece.

"Change jobs," likewise, could be calculated from standard data. Elements A and C would be figured in the office, and standard data could easily be established for Element B, as well.

As for the third job, "Carry samples," all ten elements lend themselves to the use of standard data.

STANDARD DATA EXPRESSED AS CONSTANTS AND VARIABLES.—Observers who treat each standard as a separate timing job and who do not use standard data, are not concerned with whether the elements in each study are constants or variables. Such observers would time one man walking 50 feet and allow 0.19 minutes, then in another study, time another man walking 100 feet and allow 0.38 minutes, without noting any relationship between the two studies. On the other hand, an observer who looked to the future and sought to save his own time could, from the walking time in one standard, conceivably predict the walking time for a subsequent standard. Walking time is variable. It varies with the distance walked. Elevator waits, on the other hand, are treated as constants. They are the same (on the average) regardless of the distance walked, the pounds carried, the pieces trucked, etc. Standard data, when expressed as variables, must be filed in the form of curves, formulae, or tables; when expressed as constants they can be filed in the form of a single figure: Wait for elevator #1 at first floor, 0.5 min. per wait. Constants are easier to use and there is less danger of error in their application. Since this is true, standard data should be reduced to the simplest possible form. Considered as a variable, walking time could be expressed as follows:

Distance	*0–10#*	*10#–20#*
0–5	0.0095	0.0104
5–10	0.0284	0.0312
10–15	0.0474	0.0521
15–20	0.0664	0.0730

Considered as a constant, walking time could be expressed

in terms of 0.00379 minutes per foot. Variations in loads would then show as:

Pounds Carried	*Standard Minutes per Foot of Walking Distance*
0–10	0.00379
10–20	0.00417
20–30	0.00455
Etc.	Etc.

In all cases, where there are one or more variables, the effect of one variable can be eliminated by expressing time in terms of that variable. Another example is drilling. Time varies with distance drilled, as well as with the diameter of the drill, the kind of material, R.P.M., etc. Each additional variable adds to the complications of applying the data, so by reducing all times to a "per inch drilled" basis the data are simplified to the extent of one variable. The value of this procedure in simplifying standard data files can be seen from the following calculations:

(1) Data not expressed in terms of one of the variables, if set up in the form of tables, would require separate figures in the number of—

4 kinds of material × 10 drill sizes × 21 different depths of hole (quarter inch jumps) = 840.

(2) Data expressed in terms of time per inch of depth of hole would require separate standards for only 4 kinds of material × 10 drill sizes, or 40—800 fewer standards than in example (1) above.

EXPRESSING VARIABLES IN THE FORM OF CHARTS.—If it requires exactly 0.1 minute to process 1 inch of material, 1.0 minute to process 10 inches, and 10.0 minutes to process 100 inches, it is evident that there is a direct relationship between time and inches processed. This relationship can be shown by laying off inches along the x-axis and minutes along the y-axis and plotting the resulting points on coordinate paper. The dots, when connected, will form a straight line, the position and slope of which enables the observer to determine the approximate time for processing

other lengths of material which have not been timed with the stop watch.

If the observer is undecided as to whether or not a factor causes variations in time, he can keep all other factors constant, varying only the factor in question, and by plotting the variations against the resulting times determine the degree of correlation. If the dots form a definite trend by falling along a straight or curved line, the factor causes variations in time, but if the dots fall indiscriminately, there is no correlation.

DETERMINING THE FORMULA OF A STRAIGHT LINE.—If the variation of a given factor correlates with processing times, the relationship may be shown by a line which, for most purposes, can be drawn by inspection. Standards may, of course, be taken from a chart. On the other hand, the equation of the line may be found and all possible standards for the factor in question may be found from it. Assume, for example, that stop-watch studies show the processing time for 1-inch material to be 0.01 hours, 3-inch material to be 0.02 hours, and 5-inch material to be 0.03 hours. Hours plotted against inches will produce a straight line, the equation of which may be found by the following method.

The independent variable (length) is plotted along the x-axis and the dependent variable (time) along the y-axis. The two extremes are paired, x being shown first and y being shown second; the first pair are called (x', y') and the second pair (x'', y''). Any point along the line is, of course, (x, y). The values for the first two pairs of coordinates are then substituted in the general equation for a straight line, and simplified as far as possible.

General equation: $\dfrac{y-y'}{x-x'} = \dfrac{y'-y''}{x'-x''}$

Known values: $x'=1$; $x''=5$; $y'=0.01$; and $y''=0.03$

Substituting: $\dfrac{y-0.01}{x-1} = \dfrac{0.01-0.03}{1 - 5}$

Simplifying the right side of the equation: $\frac{y-0.01}{x-1}=\frac{-0.02}{-4}$

Cross multiplying: $-4y+0.04=-0.02x+0.02$

Putting y on the left, and all other factors on the right: $-4y=-0.02x+0.02-0.04$

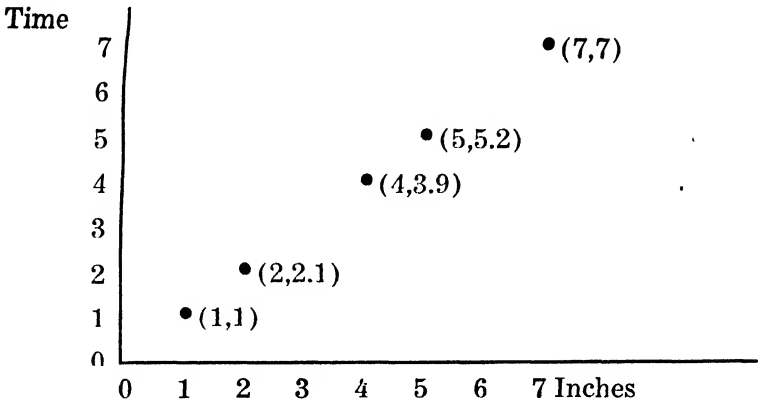
Changing signs and simplifying: $y=0.005x+0.005$

We can demonstrate the use of this formula and its correctness at the same time. We know, from a stop-watch study, that 3-inch material requires 0.02 hours for processing. If we substitute 3 in the place of x in the formula, y should equal 0.02.

$$\begin{aligned} y&=0.005\times 3+0.005\\ &=0.015+0.005\\ &=0.02 \text{ hours.}\end{aligned}$$

Similarly, time can be found for any length for which no stop-watch studies have been made. The observer should check each standard computed from such formulae to determine if the conditions under which the new job is being performed are the same which existed when the original studies were made. In the above example the extremes were 1 inch and 5 inches. It is never advisable to set standards for jobs beyond such limits without first checking to see that the operations being performed are identical. As sizes increase, it often happens that the method changes, thus invalidating the formula at the point of change.

FINDING THE LINE OF BEST FIT.—It is true that, in most cases, curves which are fit by inspection will serve the purposes of the time-study observer. If, however, it is desired to obtain a higher degree of accuracy and at the same time obtain the equation of the line of best fit, the method of least squares should be used. Let us take, for example, five standards established by means of stop-watch studies. These are represented as follows:



In order to find the formula of the line which fits most closely, it is necessary to have the following information: the sum of the x coordinates, the sum of the y coordinates, the sum of the products of each pair of coordinates, the sum of the squares of the x coordinates, and the number of pairs of coordinates. This information is tabulated and computed.

	x	y	xy	x^2
	1	1.0	1.0	1
	2	2.1	4.2	4
	4	3.9	15.6	16
	5	5.2	26.0	25
	7	7.0	49.0	49
$\Sigma =$	19	19.2	95.8	95

In the following normal equations, Σ means sum and n means number of studies. These formulae, if substitutions are made for the known factors, and if solved, will yield the formula we want.

Normal equations:

$$\begin{cases} \Sigma(y) = na + \Sigma(x)b \\ \Sigma(xy) = \Sigma(x)a + \Sigma(x^2)b \end{cases}$$

Substituting known terms:

$$\begin{cases} 19.2 = 5a + 19b \\ 95.8 = 19a + 95b \end{cases}$$

Multiplying the first term by 5, in order to get rid of one of the terms:	$\begin{cases} 96.0=25a+95b \\ 95.8=19a+95b \end{cases}$
Getting rid of 95b by subtracting one equation from the other:	$0.2=6a$
Solving for a:	$a=\dfrac{0.2}{6}=0.0333$
Substituting 0.0333 in the place of a in the first equation:	$19.2=5\times0.0333+19b$
Simplifying:	$19.2=0.1665+19b$ $19.0335=19b$
Solving for b:	$b=\dfrac{19.0335}{19}=1.0017$

It is assumed in this example that the equation we seek has the form

$$y=a+bx$$

This is the equation for any straight line. The particular equation we want is one which describes a line best fitted to the given set of data. It was stated at the outset that if the normal equations were solved such a line could be found. In substituting the data and solving we found

$$a=0.033 \text{ and } b=1.002$$

Substituting these in the above general (or generic) formula of a straight line we have the formula of the line of best fit:

$$y=0.033+1.002x$$

This formula now becomes the "standard data" formula for all sizes from 1-inch to 7-inch material for the particular job studied. The time studies previously made, and on which this formula was based, should not be used, but new times should be calculated for all sizes within the limits indicated. A table could be set up in the following manner:

For 1-inch material: $y = 0.033 + 1.002 \times 1$
$= 1.035$

For 2-inch material: $y = 0.033 + 1.002 \times 2$
$= 2.037$

And so on, through 7-inch material. Standard data in tabular form:

Length (Inches)	*Time (Minutes)*
1	1.03
2	2.04
3	3.04
4	4.04
5	5.04
6	6.04
7	7.05

Frequently, data will not fall along a straight line, but will follow a curved line. The method of least squares permits the solution of curves which follow the form:

$$y = a + bx$$
$$y = a + bx + cx^2$$
$$y = a + bx + cx^2 + dx^3$$

Etc.

The motion-study analyst is interested in the first form (the straight line) and the second form (the ordinary parabola), but he rarely uses the other forms (known as parabolas of higher order).

The normal equations for the ordinary parabola are:

$$\Sigma(y) = na + \Sigma(x)b + \Sigma(x^2)c$$
$$\Sigma(xy) = \Sigma(x)a + \Sigma(x^2)b + \Sigma(x^3)c$$
$$\Sigma(x^2y) = \Sigma(x^2)a + \Sigma + (x^3)b + \Sigma(x^4)c$$

With the given and calculated data substituted and after solving simultaneously, the values of a, b, and c are substituted in the generic formula of the parabola:

$$y = a + bx + cx^2$$

If the reader is interested in setting up charts, formulae,

and tables of standard data he should consult standard texts on statistics, algebra, and analytic geometry.[1]

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. What does the industrial manager mean by the term "standard data"?
2. What are the two chief advantages in the use of standard data?
3. Show how standard data tables can be simplified by removing the effect of one of the variables.
4. How can the effects of variations in any factor be measured with respect to their influence on processing time?
5. In what three ways can standard data be expressed?
6. For what purpose is the method of least squares used?
7. If you fit a line by inspection to plotted data, how would you go about finding its formula?

[1]Two useful books, in this connection, are Riggleman, John R., *Graphic Methods for Presenting Business Statistics*, McGraw-Hill, New York, 1936; and Philip, Maximilian, *The Principles of Financial and Statistical Mathematics*, Prentice-Hall, New York, 1940.

PART VI

SECURING THE APPROVAL OF MANAGEMENT

Chapter 22

THE REPORT

The necessity for "selling" work of a technical nature to managers has not been sufficiently emphasized in management literature. Routine reports should carry a covering letter calling attention to, and explaining, unusual variations in the figures, or, where there are no unusual features, attention should be called to that circumstance, and its reason explained.

THE TIME-STUDY REPORT.—In Chapter 20 it was pointed out that the time standard is embodied in a head sheet, a time-study sheet, and a work sheet. These are clipped together and sent to the superintendent, or some other operating official, for approval. Although this official trusts the head of standards to check carefully every standard, still he does not wish to be merely a rubber stamp. It helps, when approval of time standards is requested, if a note is attached explaining, briefly, anything which the operating official should know about the job. It should be remembered that he cannot keep up to date on all of the affairs of the standards department. Furthermore, it should be kept in mind that he sees the standard from a different viewpoint than that presented to the standards department personnel. The observer, and presumably the head of the standards department, are familiar with the details of all jobs studied—they are so close to them they often forget that others do not have such a clear picture of their intricacies. We have emphasized the importance of explaining details concerning time studies to the workmen; do not managers merit equal consideration? The action by managers of refusing to approve certain standards may seem arbitrary and incomprehensible to the standards department head until it is realized that this is a means of forcing

explanations without asking for them in so many words. A standards head may be convinced that a standard is right, but the manager is not sure. So the standard is rejected with the comment: "Too loose." It is now the standards head's move; he must prove that the standard is correct. Unfortunately, the manager has put himself on record, and we know how human beings dislike to admit themselves as having been in error. The manager will listen to all of the arguments that subsequently can be brought to bear upon the fairness of the standard and, as a rule, he will admit their weight but will end with the comment: "I still think the standard is too loose." These wasteful arguments often can be avoided if each time standard is accompanied with a few "sales" arguments as it goes to the manager's desk.

THE MOTION-STUDY REPORT.—The motion study usually results in a change of method and the purchase of additional equipment. To the analyst it is clear that a new method will or will not save money. His process charts clearly prove the case, or disprove it. But to the manager these things are not always so convincing. Every proposed change in method should be accompanied with one chart, or pictograph, showing expected savings. Several charts lead to confusion and doubt. A simple, but convincing, report should be prepared. Overwhelming evidence often has the same effect as that made on a prospect by an over-enthusiastic salesman whose statements fail to carry conviction. Managers usually want figures to support a request for an expenditure, although their general skepticism may be pointed up with the good-humored declaration that: "Although figures don't lie, liars can figure." These figures usually involve a prediction concerning the savings to be expected from the new method. Such predictions are not as dangerous to make as one might suppose, and when, subsequent to the installation of the new method, the manager descends upon the standards department in his triumphant discovery that a new method is not making the saving that had been predicted, the head of standards can easily put his finger on the cause and shift the blame to the shoulders of others. That is, he can if he made his calculations correctly

and if he can trace the source of the elements which went into the formulae he used. This statement is not made in advocacy of the common sport of "passing the buck," but the fact remains that predicting future performance, normally a risky thing to do, does not involve the head of standards to the extent that he cannot easily explain future departures from the predictions he made. He must, of course, accept responsibility for mistakes in calculations and for lack of conservatism.

COMPARING COSTS.—The Materials Handling Division of the American Society of Mechanical Engineers advocates the use of the following formulae for determining:

1. The maximum investment justified under the circumstances.

2. The yearly maintenance cost of the proposed equipment.

3. The yearly saving which can be expected as a result of the installation of the new method.[1]

The first formula is:

$$Z=\frac{(S+T+U-E)\ X}{(A+B+C+D)}$$

The second formula is:

$$Y=I(A+B+C+D)$$

And the third formula is:

$$V=[(S+T+U-E)X]-Y$$

The terms which these formulae employ are:

A = The per cent allowance on the investment.

B = The per cent allowance to provide for insurance, taxes, and similar expenses.

C = The per cent allowance to provide for upkeep.

D = The per cent allowance to provide for depreciation and obsolescence.

E = The yearly cost of items which are consumed, such as power, supplies, etc., expressed in dollars.

S = The yearly saving in direct cost of labor, expressed in dollars.

T = The yearly saving in fixed charges, operating charges, or burden, expressed in dollars.

[1]Found in Alford's *Cost and Production Handbook*, p. 882.

U = The yearly saving through increased production, expressed in dollars.

X = The per cent of the work year during which the equipment will be used.

I = Initial cost of the equipment, including delivery, installation, and shut-down expense.

An example will make the use of these formulae clear. Assume that an analyst devises a new method of performing a job, but one which involves an expenditure of $2200 for equipment. It has been demonstrated that one operator can do the work of four. The four operators each now earn $7.50 per day. It is proposed to pay the one remaining operator $2,900 during the first year. The plant will operate 300 days during the coming year. Direct labor savings will amount to $9,000 ($7.50×4×300) less $2,900, or $6,100. Because overhead remains constant, any increase in productivity means lowered costs per unit. Assume that the increase in earnings as a result of greater productivity is $650. Assume, also, that non-productive labor, in the department, carries a fixed charge of 10% of direct labor cost. It is determined that the equipment will operate 240 days during the coming year, which is 80% of the number of days the plant will operate. The allowance on investment is 6%. The insurance, taxes, etc., allowance is 4%. Upkeep is 20%. The depreciation and obsolescence allowance is 25%. And, last, the yearly cost of supplies is estimated at $450.

To find the maximum investment justified, substitutions are made in the first formula and it is solved.

$$Z = \frac{(S+T+U-E)X}{A+B+C+D}$$

$$= \frac{(6100+610+650-450)\times 0.80}{0.06+0.04+0.20+0.25}$$

$$\frac{6910\times 0.8}{0.55}$$

$$= \frac{5{,}528}{0.55}$$

$$= \$10{,}051$$

If, under the circumstances, a \$10,051 investment is justified, the new method should be adopted, for the actual investment contemplated is only \$2,200.

To find the yearly maintenance cost of the new equipment we substitute in the second formula, and solve.

$$
\begin{aligned}
Y &= I(A+B+C+D)\\
&= 2{,}200\times 0.55\\
&= \$1{,}210
\end{aligned}
$$

We are not so much interested in maintenance cost as in net saving from the use of the new equipment. This is found by substituting and solving the third formula.

$$
\begin{aligned}
V &= [(S+T+U-E)X]-Y\\
&= [(6{,}100+610+650-450)\,0.8]-1{,}210\\
&= (6{,}910\times 0.8)-1{,}210\\
&= 5{,}528-1{,}210\\
&= \$4{,}318
\end{aligned}
$$

An investment is certainly justified which pays for itself within approximately six months out of the savings for which it is responsible.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. Why is it considered to be necessary to "sell" each time standard to management?
2. Why does management often fail to approve changes in method which obviously save money?
3. Managers are interested more in expected savings than in the cost of changing to new methods. How would you go about calculating such savings and where would you get your information?
4. Of what value are charts in "selling" new methods to managers?

Chapter 23

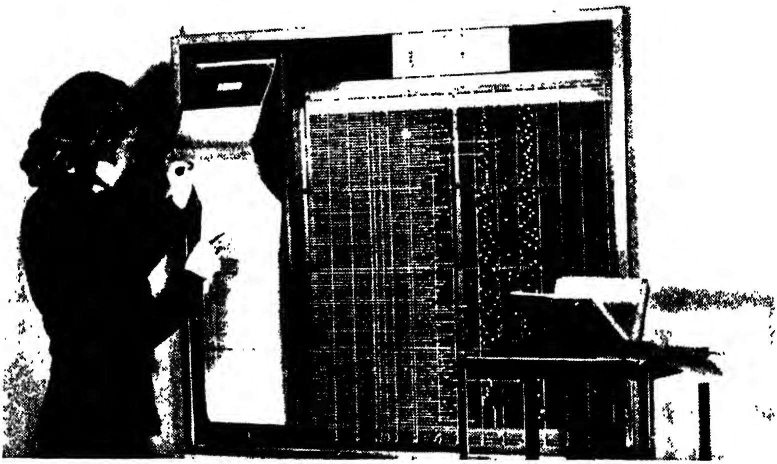
THE FOLLOW-UP

This book is being closed with the reminder that ideas, new methods, and time standards will not put themselves to work. Neither can the standards department trust others to put these changes into effect. Workers will not use new, easier methods without the encouragement of incentives and training. Management will not put new methods into effect without being convinced and constantly reminded, even though management is interested in lower costs in the aggregate. The work of devising improved methods must be followed up to see that worthy improvements are effectively utilized. This part of the work of industrial economy is just as important as any other, for the money spent in devising improvements has been wasted if these new developments are not vigorously promoted.

Every standards department should devise a system of following up each activity it performs. A schedule of motion studies should be kept up to date. Each job studied should be charted through its various stages until the improved methods devised for it have been put into effect. Some standards departments even follow up each improved job to be sure that predicted savings are accruing to the company. Habit with workers is so strong that most of them tend to lapse into old, inefficient, but familiar, methods even after careful training in the new way of working. Follow-up is needed to overcome this tendency to slip back into the old grooves. The standards department should never take the attitude: "We devised the new method—if management doesn't want to use it and if the workers won't change, that is their affair, not ours."

Follow-up is another term for control. The standards department head who does not follow up his assignments

to his observers and analysts has lost control of his department. Obviously, there are many ways of maintaining such control. A useful mechanical aid is pictured in Figure 40.



Courtesy of Produc-trol Los Angeles Company

FIG. 40—*Following up the work of a standards department.*

The details are kept in a card file and simultaneously are charted by means of colored pegs and threads which can easily be placed either vertically or horizontally on the board. Jobs which do not move along as they should, show plainly on this board, thus allowing the head of the department to quickly give his attention where it is most needed.

A good system of following up his work is indispensable to the standards department head. He must: (1) set up and follow schedules of informing supervisors and workers concerning the work of his department, (2) accumulate suggestions for layout and other changes, file them, and properly follow them up, (3) lay out and follow up schedules of routine checking of jobs for possibility of making improvements, (4) assign work to analysts and follow up the re-

sults, (5) request equipment and follow up to see that it is secured and used as planned, (6) send recommendations for new methods to operating officials and follow up to see that they are approved, (7) send suggestions for design changes, changes in materials, etc., to the proper departments and follow up to see that they are approved or reason given why change cannot be made, (8) train workers in the new method and follow up to see that the method is used properly, (9) follow up new methods to see if predictions concerning savings are being carried out properly, (10) assign work to the observers and control them, and (11) follow up requests to management and representatives of the workers concerning approval of time standards. Some concerns place the work of administering the suggestion-box system in the standards department. Often this department must, also, manage the wage incentive system. Enough, however, has been said to indicate the importance of follow-up. The manner in which this activity is handled spells the difference between a standards department which is exploiting its potentialities to the full, and one that is not.

QUESTIONS FOR SELF-EXAMINATION AND GROUP DISCUSSION

1. If management is so desirous of cutting costs, explain why follow-up of improved methods is necessary.
2. What duties of the standards department need to be followed up?
3. Can you devise a system of following up methods changes? Explain in detail.
4. What must be followed up if the standards department has jurisdiction over a wage incentive system?
5. What details would have to be followed up in connection with the administration of a suggestion-box system?

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INDEX

C

Q

R

S